

Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education

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fulfilment of the requirements for the degree of
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Declaration

I, Emmanuel Nzabonimana, hereby affirm that this research thesis is the product of my independent efforts. It is being submitted to the University of the Witwatersrand in Johannesburg in pursuit of a Doctor of Philosophy in Community Dentistry. It has not been previously submitted to any other university for a degree or examination.



Signature: _____

Emmanuel Nzabonimana

2025/02/18

Dedication

To my dear friend,

Your unwavering support and encouragement have been a guiding light throughout this journey. Your belief in me has fueled my determination to see this thesis through to completion. Thank you for always being there, for listening to my ideas, and for offering your invaluable insights. This thesis is as much yours as it is mine.

To my loving family,

Our boundless love, patience, and understanding have carried me through the ups and downs of this academic journey. Your sacrifices and steadfast belief in my abilities have empowered me to keep going. This accomplishment stands as a testament to your constant support, and I dedicate this thesis to you with my deepest gratitude.

To God,

Your divine grace has guided me and endowed me with the wisdom and strength required for this scholarly journey. In times of uncertainty, I have found comfort in your presence, trusting that with faith, anything is achievable. This thesis is a modest expression of my gratitude for your guidance and blessings.

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Abstract

Introduction

Oral diseases (OD), including dental caries and periodontitis, are a major public health problem. Poor oral hygiene is associated with OD, leading to tooth loss, disability, and compromised oral health. In Rwanda, OD is among the leading causes of morbidity at the health center level. Oral healthcare professionals are faced with considerable challenges in addressing the oral disease burden. Mobile health applications (mobile Apps) can help the individuals to manage their health and wellness, encourage healthy lifestyles, and provide valuable information as needed.

Therefore, the purpose of this study was to evaluate oral health in Nyarugenge District of Rwanda and assess the role of using a mobile App for oral health education in this community. The study objectives were to assess the knowledge, attitudes, and oral health practices (KAP) among adult participants in Rwanda, to explore the challenges faced by oral health practitioners in Nyarugenge, Rwanda; to evaluate the availability and adequacy of oral hygiene equipment, instruments, and materials. and to assess the feasibility and acceptability of a mobile App for oral health education among adults in Rwanda.

Methods

A cross-sectional quantitative study design was used to assess the knowledge, attitude, and oral hygiene practices among adults in Nyarugenge District, Rwanda. Furthermore, an audit of oral health services in Nyarugenge District was conducted. Additionally, a cross-sectional quantitative survey was used to assess the feasibility and acceptability of the mobile App for oral health education. All seven public health facilities and 14 dental professionals working in Nyarugenge were included in the study. Descriptive statistics were used to analyze the quantitative data. The interviews were analyzed using thematic content analysis. Bivariate analysis using the Chi-square test was performed to detect significant associations amongst the variables. STATA version 16 was used for quantitative data analysis, and statistical tests were conducted at 5% significance level.

Results

Among 426 participants who participated in the KAP study, 39.44% (n=168) were 18-27 years old, and the majority were female 61.5% (n=262). Poor oral health knowledge was found in 42% (n=179) of the participants, whilst 12.44% (n=53) showed poor oral health attitudes, and 67.37% (n=287) were found to have poor oral health practice. Participants with high school level of education were more likely to

have better oral health knowledge and the results were statistically significant (aOR: 1.79, 95% CI 1.14; 2.82; $p = 0.011$).

There were five health centers and two hospitals that were audited for equipment, instruments, and materials. The audit of the facilities revealed that most facilities have dental equipment and instruments, but none have adequate preventive dental instruments and materials. Most of the oral health professionals (OHPs) who were interviewed were dental therapists ($n=11$), women ($n=9$), aged 31–40 years ($n=7$), and with 11–20 years experience as oral health practitioners ($n=6$). The most significant challenges that oral health practitioners were faced with included high patient ratios to OHPs, lack of adequate and appropriate equipment and materials, patients' lack of oral health awareness, and a lack of administrative support.

The response rate for the feasibility and acceptability of a mobile App was 81% ($n=90$) of 111 participants who took part in the study. The majority of participants 44.44% ($n=40$) aged between 18 and 27 years old. Just over half of the participants were male 51.11% ($n=46$). The mobile App was found to be highly acceptable (87.78%; $n=79$) and considered highly feasible (84.44%; $n=76$) by most of the participants. The differences in acceptability and feasibility across education levels were statistically significant ($p=0.000$ for acceptability and $p=0.038$ for feasibility).

Conclusions

The findings of our study showed that 42% of the participants had poor oral health knowledge. Oral health attitude and oral hygiene practices were also lacking. There is a need to enhance oral health education of this community to improve their oral health knowledge, attitudes and practices.

Challenges faced by oral health professionals (OHPs) included staffing shortages, supply chain issues, and low patient awareness, all of which could be mitigated through better health facility management. Optimizing management could lead to more personnel, enabling OHPs to focus on education and preventive care. Additionally, ensuring access to dental resources and advocating for broader health insurance coverage for dental services would enhance service delivery. Well-established community preventive interventions, such as a mobile oral health App, could reduce the patient/provider ratio by increasing population awareness of oral health and encouraging healthy behaviours.

The study revealed that the mobile App for oral health education (BrushDJ) was highly acceptable and feasible among the participants. The mobile App had a user-friendly interface and comprehensive guidance on oral hygiene procedures facilitated by its diverse and well-integrated functions.

Keywords: Oral Health, Oral Health Knowledge, Oral Health Attitude, Oral Hygiene Practice, Oral Health Professionals, Oral Health Services, Challenges, Mobile Technology Application, Oral Health Education, Adults, Feasibility, Acceptability, BrushDJ, Rwanda.

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Nomenclature/List of Abbreviations and Symbols

CARTA	The Consortium for Advanced Research Training in Africa
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardiovascular disease
DMFT	Decayed, Missing, and Filled Teeth
HA	Alternative Hypothesis
HC	Health Centres
HICs	High-income countries
H ₀	Null hypothesis
HREC	The Human Research Ethics Committee
ICT	Information Communication Technology
IDIs	in-depth interviews
KAP	knowledge, attitudes, and practices
LMICs	Low-Middle-Income Countries
mHealthApp	Mobile health applications
MOH	Ministry of Health
NCD	Non-communicable disease
OHPs	Oral Health Professionals
Oral health App	oral health application
PI	Principal Investigator
RBC	Rwanda Biomedical Centre
RWF	Rwandan Francs
U.S	United State
WHO	World Health Organization

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CHAPTER 1

Introduction

For the purpose of this thesis, poor oral health refers to the burden of oral diseases such as periodontitis, tooth decay and tooth loss, which can be prevented with proper oral health knowledge, attitude, and oral hygiene practices of the community. Better oral health outcomes in the community depend on well-equipped oral health facilities, comprehensive services and supported oral health professionals without challenges or obstacles that impinge on providing routine oral health services. In addition, the use of a mobile App for oral health education might contribute to the raising oral health awareness. The increased awareness of oral health knowledge, attitudes, and practices might favour good oral health behaviour and lead to good oral health outcomes.

1.1 BACKGROUND OF THE STUDY

1.1.1. Burden of oral disease worldwide

According to the global burden of disease report of 2016, tooth decay was the most prevalent disease, affecting over 3.58 billion people[1]. Severe periodontal disease was estimated to be the 11th most prevalent disease globally[1]. Periodontal diseases are prevalent in developed and developing countries and affect about 20-50% of the global population[2]. Some studies have found a strong association between poor oral hygiene and common dental diseases such as dental caries and periodontal diseases[3, 4].

Globally, the burden of oral disease is high among older people and has a negative effect on their quality of life[5]. Poor oral hygiene may lead to tooth loss, which subsequently can affect the individuals' oral health and overall well-being [1, 6, 7]. Furthermore, poor oral health profoundly affects the general health and quality of life throughout an individual's lifespan by causing pain, discomfort, disfigurement, and worsening certain systemic diseases[8].

1.1.2. Burden of oral disease in high-income countries

Oral disease is still a significant public health problem in high-income countries (HICs). A study conducted in Denmark to determine the periodontal health of the adult population revealed that a

significant number of elderly individuals had severe periodontal health scores, with over 82% of older participants exhibiting pockets of 4-5 mm[9]. In the United States, over 47% of the sample representing 64.7 million adults had periodontitis, distributed as mild (8.7%), moderate (30%), and severe periodontitis (8.5%). For adults aged 65 years and older, 64% had either moderate or severe periodontitis[10]. An epidemiological study in Sweden found that the proportion of subjects with more than 4mm periodontal pocket depths increased with age[11]. In addition, the high prevalence of periodontal destruction in older people could be caused by the long-term effect of untreated, periodontal disease due to minimal oral health awareness rather than the effect of age on periodontal disease[12].

The above reports showed that HICs are still affected by poor oral health and a high prevalence of periodontal diseases.

1.1.3. Burden of oral disease in lower-and -middle-income countries

The burden of oral disease is prevalent in many low- and- middle-income countries (LMICs). In most LMICs, the general population does not benefit from routine oral health care, and preventive programs have not been established, which leads to poor oral health[5]. Various studies across China found a high prevalence of dental caries, calculus, and gingival bleeding due to poor oral hygiene[13-17]. In Andhra Pradesh, India, most respondents experienced toothache due to dental caries, and tooth extraction was the more prevalent treatment [18]. In the South zone of Delhi, India, tooth decay was also more prevalent among elderly participants in rural areas; 64% of the participants had decayed teeth, and 66.7% had root caries[19]. Toothache was the most common dental problem reported by the male and female participants followed by mobility of teeth, which was the second most common dental problem[20].

Dental treatment is often expensive, surpassing the financial capacity of many individuals in developing countries[21]. Unexpected healthcare costs can force families to allocate a large portion of their income, leading to catastrophic health spending that may drive households into poverty[22]. A study across 41 developing countries found that 6.8% of households experienced dental expenses that exceeded 40% of their financial capacity, a situation referred to as catastrophic dental health expenditure[23]. The cost of oral pain can be viewed in three ways: direct financial costs to the individual, indirect costs from lost productivity (e.g., missed work or school), and intangible costs from the suffering that affects the individual's quality of life[24]. A study in South

Africa showed that individual spending on oral pain displayed a social gradient, with those in the lowest socio-economic position spending an average of ZAR61.44, while the wealthiest spent ZAR433.83 (national average ZAR170.92). The average time lost from work or school was two days over the six-month period, but those in middle-class neighbourhoods lost the most time (3.41 days), while those in the wealthiest areas lost significantly fewer days (0.64) [25].

In Africa, oral diseases are recognised as a significant public health problem[26]. The prevalence of dental caries has risen in numerous African countries and may continue to increase due to increased sugar consumption and insufficient exposure to fluorides[26]. A high prevalence of dental caries had been found among 12-year-olds in some countries in Africa and the Middle East region from 2000 to 2011, with Gabon having decayed, missing, and filled teeth (DMFT) score of 4.9, Lebanon with 3.4, Kuwait with 2.6, and Yemen 2.2[26]. In a study conducted in Kenya, the average DMFT score of the population was 3.9[27]. The total DMFT comprised 58% decayed, 41.7% missing, and only 0.3% filled teeth. Eighty-one per cent reported a history of oral pain, 48% reported having oral pain at the survey time, and 90% of the respondents had gingival inflammation[27]. Dental caries is the most prevalent oral disease in South Africa, and almost 60% of six-year-olds have tooth decay[28]. In Nigeria, a study to determine the prevalence of dental caries and partial edentulism found that 35.1% of the participants had dental caries, and a majority had fair to poor oral hygiene[29]. In Uganda, about 65.2% of adults had $DMFT \geq 1$, and 81% of the DMFT scores were due to the decayed component. The mean DMFT score was 0.9 for children and 3.4 for adults, and calculus deposits were generally more prevalent in adults[30].

The prevalence of gingival inflammation is very high in all age groups in several African countries[31]. In the Democratic Republic of Congo, among 404 patients examined, 92 (22.8%) had severe periodontitis, 276 (68.3%) had mild to moderate periodontitis and 36 (8.9%) had healthy periodontal tissue[32]. A study conducted in Tanzania assessing self-reported halitosis found that 48.5% of respondents had halitosis. This condition is associated with bleeding gums, hard deposits, mobile teeth, and maligned teeth[33]. In Libya, a study to assess periodontal status found that 44.3% of participants had calculus, nearly 41% had shallow pockets, and 6.29% had bleeding on probing[34]. Oral disease conditions are preventable and could be addressed by appropriate oral hygiene instructions and early disease prevention. Based on the above reports,

LMICs are experiencing a high prevalence of oral diseases. Periodontal diseases and dental caries remain the common oral diseases as evidenced above.

1.1.4. Burden of oral disease in Rwanda

In Rwanda, poor oral health conditions are among the leading causes of morbidity at the health centre level[35]. An increase in oral diseases associated with poor oral hygiene, specifically tooth decay and periodontal disease, has been reported in Rwanda[36-38]. A study that assessed the prevalence and associated risk factors of periodontal disease in Rwanda found that 49.5% of the respondents had calculus, 58.9% had gingivitis, and 39.6% had periodontitis[37]. In another Rwandan study of adults aged 20 years and above, 32.4% had substantial oral debris, and 60.0% had calculus[38]. Dental caries, periodontal disease and gum diseases are the most recorded oral conditions among non-communicable diseases[35]. A cross-sectional survey conducted at Butaro District Hospital in Rwanda found that tooth extraction was predominant treatment at 97.6%. Most of the respondents had chronic pulpitis, and a few patients, 2%, received instructions on teeth cleaning and oral hygiene advice[36]. The above reports have highlighted the high prevalence of oral diseases in Rwanda.

1.1.5. Oral health knowledge

Oral health knowledge is fundamental for maintaining good oral hygiene practices and overall better oral health. Oral health knowledge is vital in promoting good health behaviours [16, 39]. People tend to adopt optimal health practices more readily when they feel empowered to control their health, which involves understanding diseases and their origins[40]. Limited health literacy is associated with negative health outcomes and reduced utilization of healthcare services [41]. In rural Nepal, it was reported that most participants lacked basic oral health knowledge, and they were less likely to seek dental services[42]. A study conducted in Germany found that a significant lack of knowledge among the participants was a risk factor for periodontal diseases. Thus, empowering communities with oral health knowledge is a preventive measure for periodontal disease [43].

1.1.6. Perception and attitudes toward oral health

The way individuals perceive and hold attitudes regarding oral health is crucial in shaping their adherence to oral hygiene practices, utilization of dental services, and overall outcomes regarding

oral health. The study among 19-year-old Swedish subjects found that adolescents with high plaque and gingivitis scores had negative perceptions and attitudes, leading to more negative behaviours towards oral health[44]. An Indian study revealed that the predominant factor hindering the participants from the practice of seeking dental care was fear, accounting for 24.3% of the respondents[20].

1.1.7. Oral health practices

Good oral health practices are fundamental for preventing dental diseases as well as promoting overall well-being and quality of life. However, some studies have identified poor health-seeking behaviour despite experiencing severe pain[13-17]. Moreover, most of the participants in the above-mentioned studies were found to have poor oral health knowledge and practices. Similarly, a study in Nigeria reported poor oral health habits, as 37.1% brush their teeth once a day[45]. The oral health education encouraged respondents in Nigeria to undergo scaling and polishing procedures as an intervention for improving oral health[46]. In Tanzania, a study assessing the frequency of poor oral hygiene found that 44.8% of the participants had fair to poor oral hygiene [47]. Oral hygiene instructions, such as dental flossing, teeth cleaning technique and duration, are mostly not given to patients by oral health professionals due to lack of time and facilities[48]. In Uganda, it was found that 56% of participants did not visit oral health facilities, and most respondents visited dental services due to pain[49]. The Rwanda National Oral Health Survey in 2018 found that the oral health status of the population was poor, with 70% of participants who did not utilise oral health services [37].

In a study conducted among school children in Pakistan, 50% of the participants did not visit dentists, 54% of subjects brushed their teeth once a day and 26% visited the dentist due to dental pain[50]. In Sudan, about 64.5% of participants considered irregular tooth cleaning to cause gingivitis. However, less than 20% of adolescents visit dentists regularly for dental checkups [51]. The above reports have highlighted that oral health practice is poor, and most people delay accessing dental services until they experience pain. The oral health promotion program should enforce early access to dental services and better oral health outcomes.

1.1.8. Oral health services and challenges facing of oral health professionals

Optimal oral health is enhanced by a comprehensive scope of services, especially preventive services. Oral health professionals face significant obstacles in delivering both preventive and

curative treatments to communities. The deficiency in infrastructure, particularly at primary health centres and community health centres, poses a significant barrier to effective oral health care delivery in India[52]. Similarly, South Africa also experiences challenges due to a lack of equipment in many dental facilities[53]. Insufficient infrastructure results in limited working stations and dental care providers, leading to prolonged patient waiting times[54]. Additionally, the scarcity of equipment and materials restricts the treatment options available and compromises the quality of care provided[54]. In Nigeria, the shortage of equipment and materials led to limited treatment options for patients, with the oral health professionals opting for treatments using available instruments and materials. Therefore, tooth extraction instead of primary preventive services has been the predominant treatment option.[55].

One of the primary difficulties faced by oral health professionals in providing comprehensive services is human resources shortages, resulting in low dentist: population ratios [56]. The shortage of oral health professionals has been reported in the United States[57], and the situation is even worse in low- and middle-income countries. The dentist: population ratio in Nigeria and Tanzania was reported to be low[58]. However, in high-income countries, it was reported to be higher compared to LMICs[3]. Many health facilities in Nigeria have only one Oral health professional, which results in challenges in referring or discussing difficult cases [55]. The affordability of dental services, the skills of oral health professionals, and the availability of dental equipment and materials all play important roles in the provision of comprehensive oral care [58].

1.1.9. Mobile App for oral health education

Oral health can be optimised by oral health awareness and education. The use of smartphone oral health applications in the medical field has been reported to improve the oral health education of the community[61]. These mobile applications (Apps) have been found to assist individuals in managing their health and wellness by promoting healthy living and providing access to helpful information whenever needed[59, 60]. A study conducted in 182 countries by Underwood and colleagues found that a mobile App for oral health education (BrushDJ) motivated respondents to brush their teeth longer. Seventy percent of the respondents reported that their teeth felt cleaner since they began using the BrushDJ mobile App, and 92.3% expressed a willingness to recommend the App to their friends and family[61]. In Saudi Arabia, the mobile oral health App significantly reduced plaque and gingival index among the respondents compared to a group who received

verbal and oral hygiene instruction alone[62]. In the Netherlands, the use of a mobile App for oral health education (“WhiteTeeth”) was found to be effective in improving oral hygiene[63]. In Nigeria, oral health education offered electronically using a recorded video showed improved oral hygiene using a debris index score among school children[64]. However, there is still a high burden of oral disease that can be prevented through various approaches, including cultivating good oral health behaviours and enhancing good oral health practices within the community. Utilizing mobile Apps for oral health education is one such approach, as the benefits of mobile Apps can contribute significantly to the global reduction of the diseases and thus improve oral health.

The findings of this thesis highlight the oral health knowledge, attitude, and oral hygiene practices of the participants in Nyarugenge District of Rwanda. Concurrently, the feasibility and the acceptability of the mobile oral health application by the participants in Nyarugenge were reported. In addition, this study provides baseline information on perceptions of oral health professionals in offering preventive oral health services. These findings will make an invaluable contribution towards improving the status of preventive services in the district. The study highlighted the perceptions and challenges of the service providers in advocating for change and support toward the provision of oral health self-care at home for individuals.

1.2 PROBLEM STATEMENT

Oral diseases are among the leading causes of morbidity at the health centres level in all age groups in Rwanda, as evidenced by the high oral disease burden[35]. Oral diseases have a multifactorial aetiology; however, they are preventable. The impact of untreated oral disease on the individual causes pain, tooth loss, destruction of periodontal tissues, and other oral problems. In addition, the impact of oral diseases on public health is huge, considering the economic, psycho-social and physical effects it has on the community[65]. As part of comprehensive oral disease management to optimise oral health, prevention of oral disease and promotion of oral health remain the most cost-effective measures to reduce the burden of oral disease [65].

Some studies have associated low health literacy with greater use of emergency care and poor preventive health-seeking behaviour for oral health services at an early stage[18, 41]. There is a correlation between limited oral health knowledge and poor oral health behaviour [66]; however, there is an absence of information on oral health awareness levels in Rwanda. In addition, there is a paucity of baseline information regarding the availability, functionality, and adequacy of

preventive infrastructure, thus hindering the understanding of factors contributing to the increase of oral disease in Rwanda. As a result, oral health interventions tend to prioritize curative services over prevention and health promotion[67]. Moreover, there are no studies that have assessed the feasibility of use of a mobile App for oral health education in Rwanda. The mobile App for oral health education has effectively improved patients' oral health and their level of knowledge in other settings [61, 63, 68]. However, in order to assess the feasibility and acceptability of a mobile app for oral health education, it is important to first understand the existing infrastructure (both physical and human) for delivering oral health education, as well as the facilitators and barriers to accessing or providing these services to the community. Therefore, the acceptability and feasibility of a mobile App for oral health education targeted to improve oral health among adults in Nyarugenge District, Rwanda, will be explored.

1.3 RESEARCH QUESTIONS

- What is the level of oral health knowledge, attitudes and practices in Nyarugenge District, Rwanda?
- What is the status of preventive oral health services offered in Nyarugenge District?
- What are the perceptions of oral health professionals regarding oral health services to the community of Nyarugenge District?
- What is the feasibility and acceptability of the use of mobile App for oral health education among adults in Nyarugenge District of Rwanda?

1.4 AIM OF THE STUDY

This study aims to evaluate oral health and examine the role of using a mobile App for oral health education in Nyarugenge District of Rwanda.

1.5 STUDY OBJECTIVES

- To determine the oral health knowledge, attitude, and oral hygiene practices in the rural and urban areas in Nyarugenge District, Rwanda.
- To undertake an audit of oral health services in Nyarugenge District.
- To explore the perceptions of oral health professionals in rendering oral health services in Nyarugenge District.

- To assess the feasibility and acceptability of using mobile App for oral health education in Nyarugenge District of Rwanda.

1.6 SIGNIFICANCE OF THE STUDY

The 2018 Rwanda National Oral Health Survey highlighted poor oral health status of the population and lack of utilisation of oral health services [38]. With Rwanda's status as a developing country, it has fewer oral health professionals to address the burden of oral health problems comprehensively. The emphasis has been on providing curative treatment to patients with pain and sepsis, thus increasing daily workloads for the few oral health professionals. The issue of having few oral health professionals affects the timing, frequency, and consistency of providing oral health education and instructions to patients. Education among other intervention is vital to empower patients to adhere to treatments and perform good oral health self-care practices at home to prevent oral diseases. The shortage of health professionals in some medical fields has been addressed by adopting telemedicine for distance consultation and drug prescriptions using mHealth Apps. The Government of Rwanda has started to invest more in information communication technology (ICT) to speed up the delivery of online health services[69]. Online health consultation has been adopted in Rwanda, where patients get consultations through phone calls by expert health professionals. In addition, Rwanda has started a project called Connect Rwanda, which focuses on bringing one smartphone per family; many citizens have received their smartphones to access online services easily[70]. However, there is still a gap in the delivery of online oral health education and information to the communities. This channel of providing education provides an opportunity to explore it for oral health education and promotion. Prior to the mobile App for oral health use, feasibility and acceptability of use is warranted. The acceptability and use of mobile App to enhance patients' oral health self-care at home has the potential to minimise the burden of oral diseases in Rwanda.

This PhD research study was conceptualized based on the following:

1. The dearth of empirical studies on oral health knowledge, attitude, and oral hygiene practices in the rural and urban areas in Nyarugenge District, Rwanda;
2. The lack of comparative analysis of the healthcare facilities for the provision of preventive oral health services offered in Nyarugenge District;

3. Exploring perceptions of oral health professionals in rendering oral health services in Nyarugenge District;
4. Contribution to health policy and health care system interventions to guide oral health self-care of individuals at home through the introduction of a mobile App for oral health education.

1.7 STRUCTURE OF THE THESIS

The divided block format has been used for this PhD thesis, following the suggested guidelines by the Faculty of Health Sciences, University of the Witwatersrand. It comprises the following chapters:

Chapter 1: This chapter has introduced the global burden of oral disease and provided an overview of oral health knowledge, attitudes, and practices globally and in Rwanda. The chapter also provided an overview of the perceptions of oral health professionals in offering oral health services, the audit of dental facility infrastructure and gave an insight into the feasibility of use of the mobile App for oral health education. The problem statement and study research question were outlined, as well as the study aims, significance, and objectives.

Chapter 2: Literature review: This chapter is a summary and critique of the relevant literature regarding the study.

Chapter 3: Methodology: This chapter describes the methods that were used in this study, highlighting the study design, study setting, study population, sampling process, data collection techniques, analysis and the ethical considerations followed for the study.

Chapters 4 – 6: These chapters present the PhD study findings under the following headings.

- Chapter 4: Oral Health Knowledge, Attitude and Oral Hygiene Practices among Adults in Rwanda. [Doi: [10.11604/pamj-cm.2024.14.4.42461](https://doi.org/10.11604/pamj-cm.2024.14.4.42461)]
- Chapter 5: Evaluation of Oral Health Services and Challenges Faced by Oral Health Practitioners Working in Nyarugenge, Rwanda
<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0309127>
- Chapter 6: The Feasibility and Acceptability of a Mobile App for Oral Health Education Among Adults in Rwanda. <https://www.dovepress.com/the-feasibility-and-acceptability-of-a-mobile-application-for-oral-hea-peer-reviewed-fulltext-article-CCIDE>

Chapter 7: Discussion and recommendation: This chapter provides an integrated discussion of the results, proposes key recommendations, and outlines areas for future research, while also describing the conclusions that bring together all the elements of the PhD thesis.

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CHAPTER 2

Literature Review

This chapter comprises a comprehensive review and critical analysis of the pertinent literature relevant to this PhD study. Emphasis has been placed on identifying knowledge gaps, particularly those central to this thesis. In Section 2.1, an extensive literature review is presented on the prevalence of oral diseases. In Section 2.2, risk factors influencing oral health were reviewed. In Section 2.3, the review was conducted on oral health knowledge, attitudes, and practices. Literature on oral health services and the perceptions of oral health professionals in providing oral health services to the community is discussed in Section 2.4. In Section 2.5, articles pertaining to the feasibility and acceptability of mobile applications used for oral health education are critically reviewed.

2.1 PREVALENCE OF ORAL DISEASES

2.1.1 Prevalence of periodontal diseases

Periodontal diseases are prevalent non-communicable diseases frequently encountered within the population. According to epidemiological data, periodontal disease exhibits a higher prevalence rate when compared to cardiovascular disease[1]. Periodontal disease is a condition that arises due to the presence of pathogenic bacteria within the dental plaque. Inflammation and infection, specifically starting as gingivitis, have the potential to manifest in the soft tissues. If left unaddressed, this inflammation can advance and lead to the involvement and subsequent deterioration of the alveolar bone, ultimately resulting in the development of periodontitis[2]. The presence of gingival bleeding, gingival enlargement, redness, and some discomfort primarily characterizes gingivitis.

Periodontitis is distinguished by the manifestation of attachment loss, gingival recession, and tooth mobility[3-5]. Periodontal disease poses a significant challenge to global public health, given its widespread occurrence, substantial economic burden, and profound health implications[6]. According to the global burden of diseases of 2016, periodontal disease was the sixth most prevalent condition, and it was estimated that 10% of the global adult population was affected by a severe form of periodontitis[3, 7]. A 2002 study performed in Portugal found a prevalence of 75.5% of periodontal disease, where 48.6% had periodontitis and 26.9% had gingivitis [4]. The

consequence of untreated periodontal disease is the destruction of supporting tissues of the teeth, with progression until teeth become loose and are eventually lost[8]. Periodontal disease is one of the main causes of tooth loss, which compromises mastication, aesthetics, self-esteem and quality of life[3].

Periodontal disease not only has a negative impact on oral health-related quality of life, but it also has a negative impact on overall health[9]. It has been associated with other non-communicable diseases such as diabetes mellitus, rheumatoid arthritis, chronic obstructive pulmonary disease, osteoporosis, cancer, neurodegeneration, and atherosclerotic cardiovascular diseases such as myocardial infarction, angina pectoris and stroke, which increases the mortality risk of those patients[3, 6, 9-11]. Furthermore, periodontal diseases have also been associated with adverse pregnancy outcomes such as preterm delivery and low birth weight, pre-eclampsia and eclampsia, and gestational diabetes [12, 13]. Periodontal disease is mainly linked to poor oral hygiene practices, as well as lifestyles, such as smoking and diet, which is the reason why an emphasis should be put on the common-risk factors approach to prevention[14, 15].

Accumulation of dental plaque and poor oral hygiene are the significant risk factors for periodontitis. A higher prevalence of periodontal diseases was observed among Rwandans in a study aimed to determine the prevalence and associated risk factors of periodontal disease. Findings showed that 49.5% of the respondents had calculus, 58.9% had gingivitis, and 39.6% had periodontitis[16]. In Libya, a study to assess periodontal status found that 44.3% had calculus, nearly 41% had shallow pockets, and 6.29% had bleeding on probing[17]. In a study from Sudan, about 64.5% of participants considered irregular tooth cleaning to cause gingivitis. However, less than 20% of adolescents visit dentists regularly for dental checkups [18]. The prevalence of periodontal disease in Saudi Arabia was 71.3%, and 53.1% of the participants had fair oral hygiene[19]. The prevalence of plaque and gingival bleeding upon probing in Tanzania was 100%, with 13.9% of individuals reported experiencing unpleasant mouth-breath [20]. In the study conducted in Rwanda to assess periodontal disease prevalence among patients attending the University clinic in Nyarugenge District, 41.6% had periodontal diseases, significantly increasing with age[21].

2.1.2 Prevalence of dental caries

Dental caries is characterised by the progressive destruction of the hard tissues of the tooth through a process of rapidly alternating demineralization and remineralization. Tooth destruction happens when the process of demineralization surpasses the process of remineralization.[22]. Four factors have been identified to play a role in the destruction of tooth tissues:- the bacteria present in the oral cavity, especially *Streptococcus mutans*, the food substrates, the time it takes for these to interact and the tooth structure for the interaction[23]. When someone eats and does not brush his/her teeth, some food remains entrapped in the fissures and pits of the occlusal surfaces or the interdental spaces of the dentition. If there are some fermentable carbohydrates, *streptococcus mutans* transform them into acid, which attacks the tooth surface, causing demineralization. The initial sign of that demineralization is a white spot, which later progresses into a cavity and deepens[24, 25].

The disease invades the pulp when no treatment intervention is done, which is the only vascularised tissue of the tooth enclosed inside the hard tissues. When the demineralisation reaches the pulp, it is called pulpitis, and at that time, the pain becomes continuous, throbbing, and unbearable, especially during the night, to the point of causing sleepless nights[26, 27]. During this period, patients commonly seek dental care, frequently expressing a strong desire for tooth extraction. Convincing them of the existence of alternate treatment to maintain the tooth can be difficult. Conversely, certain individuals choose to get analgesics and delay seeking dental care from oral health professionals[28]. Thus, the acute phase of pulpitis follows, but the disease keeps progressing to chronic pulpitis and eventually to pulp necrosis[29]. With time, the infection reaches the periapical region, causing a periapical abscess[30], which later develops into a periapical cyst[31], which in turn leads to a periapical granuloma[32] with a possibility of reversal. When nothing is done, the alveolar bone keeps resorbing with the extension of the lesion, ultimately leading to tooth mobility and tooth loss. The pain and the resulting loss of teeth due to dental caries negatively impacts the overall quality of life. In fact, apart from the working days lost due to the disease or its treatment, there are economic costs from opportunity costs of absence from work or school and direct costs from money spent on dental caries treatment. Furthermore, the loss of teeth has an effect on the patient's aesthetics and social life[33].

Dental caries, periodontal diseases and gum diseases are the most recorded among non-communicable diseases [34]. The prevalence of dental caries was 72.8% among adults aged 17 to 75 years old in Kosova, Europe[35]. In the Indian state of Andhra Pradesh, 42% of 18-year-olds and above have experienced dental problems, and toothache associated with dental caries is the most experienced dental problem(46.32%), and common treatment is tooth extraction[36]. In another study conducted in the South zone of Delhi, dental caries was more prevalent among elderly participants, with 64% having decayed teeth and 66.7% having root caries[37]. In Northeast China, the prevalence of dental caries in the elderly population was 67.5%, and 80% had lost their teeth due to dental caries, and the prevalence was higher in urban areas [38]. In Tanzania, a study conducted among subjects aged 14 and 44 years found that tooth decay was prevalent in 54.6%, whereby 21.9% had pulpitis, and 57.3% of the participants had lost their teeth due to dental caries[20]. In Nigeria, a study to determine the prevalence of dental caries and partial edentulism found that 35.1% of the participants had dental caries, and the majority had fair to poor oral hygiene [39]. The studies in Eastern African countries reported the overall prevalence of dental caries to be 45.7% among the participants. The highest prevalence was in Eritrea at 65.2%, Sudan at 57.8%, and Tanzania at 30.7%[40]. A scoping review of 8 peer-reviewed papers revealed a higher prevalence of dental caries in Rwanda, ranging from 42.42% to 71.5%[41].

2.1.3 Prevalence of tooth loss

Caries and periodontal diseases have been found to be the main cause of tooth loss. However, the early interception of caries and periodontal disease is a better way to minimize the extraction of teeth [42]. A systematic review to identify the reasons for tooth removal among adults found that the proportion of all extractions varied between 36.0% and 55.3% for caries, 24.8% to 38.1% for periodontitis, 0.8% to 4.4% for trauma, 7.3% to 19.1% for periapical disease, 2.5% to 7.2% for orthodontics, and 4.5% to 9.2% for other reasons[43]. Nevertheless, the probability of tooth extraction remains influenced by demographic variables, including age, socioeconomic position, and educational attainment. The prevalence of extractions may be increased among older persons because of age-related oral health conditions, including periodontal disease and tooth decay[44, 45].

Individuals from lower socioeconomic backgrounds or with limited access to dental care may face barriers to timely early treatment, leading to a higher incidence of tooth extraction for preventable

dental conditions[42, 46].In Rwanda, tooth extraction as treatment intervention was common at 97.6%, according to a cross-sectional survey conducted at Butaro District Hospital. The majority of the respondents had chronic pulpitis, and a few patients, 2%, received care consisting of teeth cleaning and oral hygiene advice[47]. Systematic reviews identified periodontal disease and dental caries as the leading causes of tooth loss among adults. However, both dental caries and periodontal diseases are preventable [48, 49].

2.2 FACTORS AFFECTING ORAL HEALTH

2.2.1 Risk factors affecting oral health

A myriad of modified risk factors, such as poor oral hygiene, oral health behaviour, diets rich in sugar, tobacco use, age, socio-economic/geographic/rural vs urban and increased consumption of alcohol, influence oral health. These factors encompass individual behaviours, systemic conditions, and environmental factors [50, 51]. The risk factors associated with periodontal diseases were poor oral hygiene, older age, irregular dental visits, and education level[16]. Other factors playing a pivotal role in the prevalence and severity of oral diseases include periodontal disease, dental caries, and oral cancer[52]. Identification and comprehension of these risk factors are imperative for formulating effective approaches for preventive and intervention strategies aimed at enhancing oral health and overall well-being[52]. For instance, extensive research has highlighted the detrimental effects of tobacco use on oral health, including increased risk of periodontal disease, oral cancer, and tooth loss[53]. Similarly, excessive alcohol consumption has been linked to oral cancer, periodontal disease, and compromised wound healing following dental procedures[54]. Moreover, poor dietary habits, characterized by high sugar consumption and low intake of fruits and vegetables, contribute significantly to the development of dental caries and periodontal disease[55]. Inadequate oral hygiene practices, such as irregular brushing and flossing, can exacerbate plaque accumulation, leading to gingivitis and periodontitis[56]. Smokers tend to have more significant mean probing attachment loss in all age groups[57]. In addition, smoking is significantly associated with severe chronic periodontitis, a higher dental plaque level, and poorer oral hygiene[58-60]. Non-smokers had statistically significantly better oral hygiene than smokers[60].

2.2.2 Poor oral hygiene

Poor oral hygiene is prevalent in many developing countries. According to a study conducted in Odisha, India, to assess the oral hygiene status among adults, 85% of the participants had poor oral hygiene[61]. Poor oral hygiene was 44.8% among participants in a study conducted in Tanzania[62]. Rwanda National Oral Health Survey found that among adults who were 20- years of age and older, 32.4% had substantial oral debris, and 60.0% had calculus[63]. Another study to explore the participant's knowledge, attitude, and practices on oral hygiene found that most respondents have poor oral hygiene; 60% of them had calculus[64].

Suboptimal oral hygiene had a negative impact on the community. According to a study conducted in India, adult participants with poor oral hygiene had a higher prevalence of periodontal diseases[61]. A systematic review aiming to estimate oral hygiene effects on periodontitis found that fair to poor oral hygiene increases the risk of periodontitis[65]. However, the risk can be reduced by regular tooth brushing and regular dental visits.

Poor oral hygiene leads to dental halitosis. The effects of halitosis on personal well-being include compromised individual self-esteem and social discomfort with peers[66]. A study conducted in Tanzania aimed at assessing self-reported halitosis found that 48.5% of respondents had halitosis. This condition is associated with bleeding gums, hard deposits, mobile teeth, and misaligned teeth[66]. According to the Rwanda National Oral Health Survey findings, most adults had poor oral health with both hard and soft debris[67]. Improving oral hygiene alone has been shown to improve periodontal health for patients with chronic periodontitis. Failure to improve oral hygiene has been found to increase oral disease in society[67].

2.2.3 Systemic diseases associated with poor oral health

Systemic diseases are a significant risk factor for Poor oral hygiene/ oral diseases [49], and oral disease has a profound impact on individuals' quality of life[52]. The prevalence of periodontitis is higher among patients with chronic obstructive pulmonary disease (COPD), at 58.1%, compared to healthy patients without COPD at 34%[49]. Another study found that poor oral hygiene and gingival disease were significantly associated with infective endocarditis-related bacteraemia[68]. The study conducted in India among 200 participants found that severe periodontal diseases were significantly associated with the occurrence of systemic diseases [69]. People with severe

periodontitis had a 25% increased risk of coronary heart disease compared to those with minimal periodontal disease [70]. Systemic diseases, including diabetes and cardiovascular diseases, are closely associated with poor oral health, with evidence suggesting bidirectional relationships between these conditions and periodontal disease[71, 72]. Early childhood caries have been associated with upper respiratory infections among children[73].

In conclusion, the link between systemic diseases and poor oral hygiene is clear and significant. Oral diseases not only impact individuals' quality of life but also increase the risk of various systemic conditions such as chronic obstructive pulmonary disease (COPD), infective endocarditis, coronary heart disease, diabetes, cardiovascular diseases, and early childhood caries.

2.3 ORAL HEALTH KNOWLEDGE, ATTITUDE AND PRACTICES

2.3.1 Oral health knowledge

The classical Knowledge-Attitude-Practice (K-A-P) theory posits that knowledge will positively influence one's attitudes towards a phenomenon, and the attitudes will, in turn, influence one's behaviour[74]. Therefore, good oral health practices are informed by optimal knowledge and positive attitudes as postulated by the K-A-P educational theory[74]. Oral health knowledge is an essential requirement for health-related practices and better oral health. Such knowledge is crucial for developing healthy behaviours [75, 76]. Individuals are more likely to adopt optimal health-related practices when they have a greater sense of control over their health, which includes a better understanding of diseases and their causes[77]. There exists a correlation between limited health literacy and unfavourable health outcomes, as well as insufficient utilization of healthcare services[78].

Awareness of the causes and prevention of oral diseases was a motivating factor in promoting good oral health behaviour. A study conducted in Zambia was carried out to assess the knowledge of periodontal diseases, oral hygiene practices, and self-perceived periodontal problems among pregnant and postnatal women aged 15-43 years. The findings revealed that 87.4% of participants were aware of the signs of gingivitis, with 93.3% recognizing bleeding as a symptom of gingivitis, and 62% of the participants were aware of periodontal diseases[79]. In a research conducted among Chinese aged 20 years and above, 63.7% of the participants had no prior knowledge of periodontal disease. Additionally, over 75% of this population were unaware of any symptoms linked to the

condition[80]. In rural Nepal, reported that most participants brushed once a day, lacked general oral health knowledge regarding oral diseases, and were less likely to visit dental services[81].

A study conducted in Pakistan to assess oral hygiene knowledge, attitude, and practice among school children aged 12-14 years found that 64% of children did not know about fluoride, and 50% of children did not visit dentists. The majority of subjects, accounting for 54%, brush their teeth once a day and 26% of the participants reported visiting the dentist due to pain [82]. In Germany, a study aimed at assessing periodontitis-related knowledge and its relation to oral health behaviour in a community found a limited level of knowledge concerning all topics among the participants[83]. No consistent relationships with age or education were observed, although less educated individuals, very young, and older adults tended to display the most significant deficit in knowledge[16]. The study suggests that health education regarding periodontal diseases needs enhancement at the community level. Specifically, schoolchildren, older citizens, and those with lower educational attainment were identified as the groups most in need of targeted interventions. These interventions should prioritize preventive measures[83].

2.3.2 Oral health attitude and practice

As postulated by the K-A-P theory[74], positive attitudes and favourable practices and habits may be a result of a good oral health education activity. Establishing and adhering to a routine of healthy habits and maintaining optimal oral hygiene practices, such as engaging in twice-daily tooth brushing, play a pivotal role in the prevention of gum disease and the promotion of overall oral well-being.

The Social Cognitive Theory emphasizes that behavior is shaped by the interaction of three factors: personal cognitive factors (including self-efficacy and outcome expectations), behavioral factors (such as habits or practices), and environmental factors (such as access to resources and social support)[84]. In oral health, individuals with high self-efficacy are more likely to engage in regular brushing and flossing, while those with low self-efficacy may avoid these behaviors due to a lack of confidence[85]. Individuals are more likely to adopt oral health behaviors if they believe these actions will lead to positive outcomes, like preventing cavities or bad breath [85]. People learn by observing others. Children who see parents brushing their teeth regularly are more likely to adopt similar behaviors. Positive role models, like dentists, also encourage healthy practices [86]. Access

to dental care and oral health products influence behavior. Those with limited access may struggle to maintain healthy oral practices, despite positive attitudes and knowledge[85].

In India, oral healthcare-seeking behaviours among Pedakakani Mandal people were poor, and over 20% reported tobacco use, and 14.1% reported alcohol use[36]. In North Florida, adolescents aged 12 to 18 years believed that their oral disease risk was reduced by brushing and flossing[87, 88]. The study to analyse oral health-related perceptions, attitudes and behaviours concerning oral hygiene conditions among 19-year-old Swedish individuals found that adolescents with high scores of plaque and gingivitis had less positive perceptions, attitudes, and behaviours towards oral health[88]. A study conducted in Zambia among pregnant and postnatal women aged 15-43 years found that 38.5% brushed twice a day using a plastic toothbrush, while only 2% used dental floss[79].

In Uganda, a study found that 56% of respondents did not visit oral health services in two years, and most respondents visited dental services due to pain[89]. Another study in India evaluated oral healthcare-seeking behaviour in a rural population in central India. Fear of the dentist was found at 24.3% to be the primary reason for not visiting the dentist, and toothache was the most common dental problem reported[90]. A study found that oral hygiene practices are not common among Saudi Arabian people, and oral disease prevention is limited, with 85% never flossing their teeth and 16.3% never brushing their teeth[91]. Subjects holding more favourable beliefs had better self-rated oral health with less gum bleeding on probing, less plaque, and fewer dental caries[92]. Good oral hygiene behaviour appeared to be highly effective in controlling plaque following a brief intervention[93]. In the study among 35-44 and 65-74-year-old Chinese, 15% of them would visit an oral health professional if they had bleeding gums. In contrast, 60% of the participants paid no attention to the apparent signs of caries if there was no pain, and only 6% of the participants had a regular dental checkup in the past two years [94]. According to the Rwanda National Oral Health Survey, among 2097 participants, 70.6% had never visited dental services, and 98.7% visited dental services due to pain[63]. Another study in Rwanda found poor oral health practices where 69.7% of participants brushed once per day, and 98% did not use dental floss. A significant majority of participants, specifically 94.9%, sought dental services exclusively in emergencies. Furthermore, it was observed that the oral hygiene condition among these individuals was suboptimal[16].

In China, nearly 15% of the subjects would visit a dentist if they experienced bleeding from gums; the majority brushed at least twice a day, but only 5% used fluoridated toothpaste[94]. A regular dental checkup was low, and only 6% went for a checkup in the last two years[94]. In Nepal only 3.9 % visited dental services in the last six months[95]. A study conducted in Nigeria found that the majority reported poor oral health utilization habits, as 37.1% clean their mouth once a day [96]. Dental flossing effectively reduces interproximal bleeding, while tooth brushing reduces gingival bleeding by 35%[97]. In a US study to determine factors associated with the use of preventive dental and health services among adolescents, 32% of the respondents had never had a dental examination[98]. Poor dental-health-seeking behaviour was the most reported poor practice in many settings[75].

In India, a study found that the majority of the workers brushed their teeth once daily (78.9%) with a toothbrush (51.5%) and used toothpaste (41.2%) [61]. In Nepal, 94.9% of respondents brush their teeth once a day. Another study investigating the relationship between oral hygiene practices of dentate older adults living in residential homes found that 31% of the population cleaned their mouths twice daily without requesting help, and 69% cleaned less often[99]. Good oral hygiene practices, such as tooth brushing and tooth flossing, had a significant effect in reducing gingivitis compared to toothbrushing alone[100].

2.4 ORAL HEALTH SERVICES

2.4.1 Perceptions of oral health professionals

Optimal oral health will be realised through the complementary and supplementary actions of both the users and the providers of dental services as well as the status of the infrastructure. Oral health professionals are confronted with numerous challenges in the provision of oral health services, which impact patient access, quality of care, and professional practice. Oral hygiene services are crucial in maintaining good oral health and preventing the progression of oral diseases. The lack of resources and dental materials is a major obstacle to delivering the necessary oral health services to the community. Furthermore, the high patient-to-professional ratio becomes another obstacle for oral health professionals when delivering oral health education to every patient in the community. Oral hygiene instructions, such as dental flossing, teeth cleaning technique and duration, are mostly not given to patients by oral health professionals due to a lack of time [101]. The availability of oral health professionals who provide oral hygiene services to the community

will assist in the reduction of gingival inflammation and the improvement of periodontal probing depth[58, 102].

2.4.2 Financial challenges

Dental treatment comes with a high cost that exceeds the financial reach of many individuals in developing nations[103]. Governments globally have been urged to adopt universal health coverage for their populations[104, 105]. It is advocated that with universal health, all individuals will access necessary healthcare services without enduring financial hardships [104, 105]. Despite recent endeavours to explore alternative healthcare financing methods[106, 107], out-of-pocket payments remain the primary means of funding healthcare services in LMICs[104, 108]. Significant and unforeseeable healthcare expenses might cause families to dedicate a large amount of their available income, resulting in catastrophic health spending that can potentially push households into poverty[109]. Millions of individuals worldwide are affected by oral diseases, resulting in an annual spend of US\$298 billion for the treatment of widespread oral diseases. This figure represents 4.6% of the global expenditure on healthcare[109-111]. Even in United States, where private dental insurance coverage is extensive, out-of-pocket costs constitute a substantial portion of the overall dental expenditure[112, 113]. Dental treatment is extremely expensive and beyond the capacity of many individuals in developing countries.

A study conducted across 41 developing nations revealed that 6.8% of households faced dental expenses that exceeded 40% of their financial capability to cover costs, termed catastrophic dental health expenditure[114]. In South Korea, households utilizing dental services had a higher proportion of catastrophic dental health expenditure compared to those that did not seek these services[115]. In Iran, households that accessed dental services were, on average, four times more prone to experiencing catastrophic dental health expenditure compared to those that did not utilize dental services[116]. The primary challenge highlighted by researchers revolves around financial constraints, given the high costs associated with dental services, which are often considered among the most expensive healthcare treatments[103]. As a result, dental care becomes challenging to access, particularly in low-income countries. Even in higher-income nations, individuals with lower incomes, elderly populations, and marginalized communities like refugees, migrants, and individuals with disabilities face difficulties affording these services[117, 118].

In the United States, a larger number of individuals report encountering financial obstacles when trying to access dental care, regardless of their age, income bracket, or insurance coverage, compared to other forms of healthcare. National insurance schemes often do not fully cover many treatments, offering a limited scope of services[119, 120]. When faced with financing challenges, health professionals tend to prioritize clinical procedures that offer higher compensation rather than focusing on risk assessment or preventive measures[121]. Many oral health professionals prefer working in private dental clinics where they can earn higher incomes[121]. Public institutions are reported to be primarily populated by those who lack the financial means to acquire expensive dental procedures[122]. Singh et al. stated that the primary focus of most dentists is on financial gain[123].

Several studies have emphasized the inequalities in accessing oral healthcare services, especially in underserved communities and rural regions. Elements like socioeconomic status, geographic location, and insurance provisions substantially constrain individuals' capacity to access and obtain dental care[46, 113]. Hence, certain dental services are unavailable in public institutions due to payment-related difficulties.

2.4.3 Infrastructure for dental services

The availability, functionality, and adequacy of dental equipment, instruments, and materials are crucial aspects of ensuring effective oral healthcare delivery within dental facilities. However, the delivery of oral health services faces challenges due to inadequate infrastructure, equipment, instruments, and materials. The absence of proper infrastructure at primary health centres and community health centres poses a significant obstacle to delivering oral health services in India. This issue might stem from the absence of dentists in government decision-making bodies[123]. In care homes for the elderly in Germany, the infrastructure problem persists, and oral health professionals advocate for the installation of at least one dental chair equipped with a light in every care facility[124]. The availability of equipment is also a problem in South Africa in many dental facilities[121]. The lack of infrastructure leads to few working stations and few dental care providers, causing long patient waiting times, and the lack of equipment and materials impinge on the options and quality of treatments[125]. The scarcity of equipment and materials as reported in Nigeria poses a potential risk to the treatment options for patients and may lead oral health professionals to prioritize treatments that have access to instruments and materials [120]. The

Rwanda National Strategic Plan for Oral Health 2019-2024 noted that dental equipment, notably dental chairs in district hospitals, were not effectively functional due to low maintenance capability[126].

2.4.4 Oral health human resources

The biggest challenge experienced by oral health professionals when offering services is linked to a shortage of human resources, which leads to low dentist/patient ratios[127]. Different dental specialists are needed to collaborate in comprehensive oral examinations and treatment[128]. The problem of a shortage of dentists has been reported in the USA[129], and the situation is exacerbated in Low- and Middle-Income Countries (LMICs). For instance, in 2017, the ratio of dentists to patients in Nigeria was as dire as 1:38,600, and in Tanzania, it stood at 1:360,000[130]. In contrast, in high-income nations, this ratio was significantly better, at 1:2,000[52].

Many health facilities in Nigeria have only one Oral health professional who does not have colleagues to consult about difficult cases[120]. The increased workload allocated to oral health professionals makes them overlook important steps in the diagnosis process, such as comprehensive oral examinations and care and oral health education. It is important to do a comprehensive oral examination, including screening for early signs of all oral diseases, because it has been observed that most patients consult only for pain and dental emergencies[27, 131]. Therefore, preventive measures are often neglected despite one of the goals of oral healthcare being a commitment to prevention[121, 123].

The adoption of oral health preventive measures cannot take place if oral health professionals do not educate patients on good oral hygiene practices such as frequent brushing, good brushing technique, interdental cleaning, regular dental check-ups, diet, and smoking cessation for the prevention of both periodontal diseases and dental caries[129]. Some managerial barriers to good and equitable oral health identified in the literature include unclear goals, inadequate organization and management, poor planning, little emphasis on evaluation, and failure to plan for adequate human resources and use of auxiliaries[123]. It has been observed that dental service is often neglected during recruitment and procurement processes[120, 122]. The literature demonstrates that there is international neglect and a lack of political prioritizing of oral health [129, 132]. Many public policymakers do not value oral health as part of general health, making it a lower

priority[123]. The affordability of dental services, the skills of oral health professionals, and the availability of dental equipment and materials all play important roles in the provision of comprehensive oral care, and this is the responsibility of the management of health facilities[131].

Oral health professionals encounter a multitude of challenges in providing oral health services. The way of addressing those challenges requires multifaceted approaches, including policy changes, increased education and awareness, and innovative solutions to improve access to care and support dental practitioners.

2.5 MOBILE APP IN ORAL HEALTH EDUCATION

2.5.1 Oral health information

Historically, oral health professionals have been responsible for providing oral health education to the community, as they possess the necessary skills and expertise in this domain. Nevertheless, it is crucial to acknowledge that the current availability of oral health professionals falls short of addressing the escalating global prevalence of oral diseases[122]. The considerable burden of work and extended waiting periods for treatment presents a notable obstacle for the populace in accessing prompt oral health education.

The challenge of obtaining dental care is further amplified by various factors, including the financial burden associated with appointments and the significant time commitment required to commute to healthcare facilities. As a result, these factors combine to form a considerable obstacle for the community at large. The complexity of this challenge is heightened by the circumstance that individuals who can obtain oral health information within these facilities frequently present with pre-existing severe oral conditions, which can detrimentally impact their overall well-being. Insufficient dissemination of oral health information within society may potentially contribute to the notable increase in oral health issues observed within the community. To address these challenges, it is crucial to prioritize the utilization of mobile technology. This approach is of utmost importance as it provides a solution that is readily available to a large portion of the population[133, 134].

2.5.2 The use of mobile technology in oral health

The knowledge of oral health is an important element of good oral health because it influences positive attitudes and good practices. Oral health awareness and education can be conducted using different channels and media. Several studies have focused on using mobile apps to promote oral health (31/45, 69%) via mobile phones, with behavior management (5/45, 11%) being the next most common focus. The literature shows that the use of mobile apps for oral health is increasing, particularly among children and adolescents[135]. The utilization of mobile technology, specifically smartphone applications, holds great promise in addressing the disparity in oral health education. These applications offer a convenient and easily accessible platform for individuals to acquire crucial knowledge regarding the maintenance of optimal oral health[133, 134]. Through the strategic utilization of mobile devices, there exists a tremendous opportunity to distribute oral health information widely. This dissemination of knowledge has the potential to contribute significantly to preventive endeavours and, in turn, alleviate the overall burden of oral diseases within the community.

The utilization of technology has facilitated the emergence of mobile app-based oral health education, which holds great potential in effectively tackling the challenges mentioned earlier. This innovative approach offers a convenient means of delivering fundamental oral health education to individuals, regardless of their location, without the need for transportation or enduring lengthy waiting times at healthcare facilities to access oral health information. These applications have the potential to facilitate individuals in managing their health and wellness, fostering a culture of healthy living, and conveniently accessing valuable information as and when required. Underwood and colleagues undertook a study to assess the impact and effectiveness of utilizing mobile technology to improve health behaviours. Their research unveiled that the BrushDJ mobile application for oral health successfully motivated individuals to prolong their toothbrushing sessions. Additionally, a substantial majority, around 70% of the participants, noted experiencing cleaner teeth after integrating this oral health app into their daily regimen. Notably, an impressive 92.3% of the respondents indicated their readiness to recommend this app to others [136].

The mobile App oral health education had the potential to address the challenges by providing easily accessible and comprehensive oral health education to individuals regardless of their location. The mobile App will eliminate barriers such as transportation issues and long waiting

times typically associated with obtaining oral health information at healthcare facilities. These applications have the potential to empower individuals in effectively managing their health and well-being, fostering a culture of healthy living, and facilitating convenient access to valuable health-related resources[136].

A study conducted in Saudi Arabia revealed that the utilization of mobile oral health applications demonstrated a positive impact on encouraging individuals to engage in regular tooth-brushing practices. The findings of this study indicate a notable reduction in plaque and gingival index following four weeks of utilizing a mobile application, as opposed to receiving verbal instructions for oral hygiene[137]. In the Netherlands, a mobile application known as "WhiteTeeth" has been identified as a valuable tool in enhancing oral hygiene, as per research findings [138]. In the context of Nigeria, it has been observed that the provision of oral health education through electronic means, specifically recorded videos, has shown promising results in enhancing oral hygiene among school children[139]. This intervention has been associated with a reduction in the debris index score, indicating a positive impact on oral health outcomes. A study by Marchetti et al. has demonstrated that the utilization of mobile Apps can play a crucial role in enhancing the retention of oral health knowledge following a post-test, in comparison to individuals who solely received verbal health guidance[140]. The findings of the study indicate that individuals who were provided with access to a mobile App demonstrated higher levels of knowledge retention during the follow-up test and post-test, as compared to their performance in the pre-test [140].

2.5.3 The usage of smartphones in healthcare

The frequency of smartphone usage has experienced a significant surge on a global scale in recent years. In 2016, the number of smartphone users worldwide exceeded 2 billion, and it was projected that by 2018, this figure had reached approximately one-third of the global population[141]. The exponential increase in smartphone usage, coupled with the inherent features of mobility and widespread appeal, presents an unparalleled prospect for the development of applications aimed at promoting health and influencing health-related behaviours[141]. Mobile devices, such as smartphones, possess unique attributes that make them well-suited for delivering personalized healthcare support[142]. These devices enable health information interventions to be delivered in a timely manner, ensuring that individuals receive the necessary assistance when it is most relevant and beneficial to them[142]. Mobile health applications, commonly known as mHealth apps, hold

great promise in engaging patients and empowering them to participate actively in their healthcare. Mobile health (mHealth) applications have demonstrated their potential as effective tools for promoting behaviour change in the context of health prevention and self-management[142, 143]. These apps are widely accessible and conveniently portable, making them highly advantageous in supporting individuals' efforts to adopt healthier habits and manage their well-being. The significant influence of mHealth apps on various crucial aspects of health, including the management of chronic diseases, mental health, and patient education, has been extensively documented [142, 143].

The growing usage of mHealth apps necessitates a heightened focus on their efficacy. Nevertheless, it is important to acknowledge that notable obstacles exist when it comes to broadening the scope and effectiveness of mHealth apps in enhancing the well-being of individuals and, in turn, the overall populace[142, 143]. To maximize the usefulness of mHealth apps, it is crucial to integrate the requirements of their target users during the design phase[144, 145].

The smartphone represents a remarkable advancement in technology, seamlessly integrating the functionalities of mobile communication and computing into a compact, handheld device. Additionally, it offers the convenience of running diverse third-party applications, further enhancing its versatility and utility[146]. The current iteration of smartphones is being increasingly recognized as a compact computer rather than solely a mobile phone. This shift in perception is primarily due to the device's robust computational capabilities, expansive storage capacity, generous screen size, and the presence of an open operating system that fosters the creation and advancement of applications[147]. Simultaneously, there has been a noticeable increase in the prevalence of medical applications being utilized by individuals [148, 149]. According to conducted studies, a significant majority of health professionals, specifically over 85%, have been observed to utilize smartphones in their daily routines[150, 151]. Furthermore, a substantial proportion, ranging from 30% to 50%, have been found to incorporate medical applications into their clinical practices[150, 151].

Additional research findings have also indicated that the utilization of mobile dental applications has the potential to effectively encourage individuals to adopt positive oral hygiene practices and enhance their overall oral health[136]. Dental applications have proven to be an effective and innovative approach to delivering patient education. In 2016, Pulijala et al. developed a mobile

application with the purpose of offering patients access to 3D visualized information pertaining to orthognathic surgery. The study revealed that patients who were provided with 3D visualized information through the app demonstrated a higher level of accuracy in answering questions related to orthognathic surgery compared to the control group[152]. In a separate research investigation, Ala et al. discovered that the utilization of a dental application proved to be a highly effective method for disseminating easily accessible knowledge to assist individuals in effectively managing tooth avulsion. Furthermore, their findings suggest that this approach may even surpass the traditional method of delivering information through lectures[153]. In 2014, Chia-Yung Lin et al. developed a dental application in Taiwan that integrated cloud services to enhance the convenience of scheduling appointments for both dentists and patients. The study conducted by the researchers revealed that the newly developed dental application has the potential to offer streamlined services to both oral health professionals and patients. Furthermore, it can foster improved communication and rapport between these two key stakeholders in dental care[154].

Based on the extensive literature findings presented, it is evident that mobile technology holds immense promise in aiding the community in its endeavour to uphold optimal oral health. Regrettably, there remains a dearth of comprehensive data pertaining to the utilization of mobile applications for oral health promotion in the African region.

2.5.4 The state of mobile technology in Rwanda

The findings of the 2018 Rwanda National Oral Health Survey shed light on the suboptimal oral health conditions experienced by the population, as well as the limited access and utilization of oral health services[63]. In the context of Rwanda's status as a developing nation, it is important to acknowledge the limited availability of oral health professionals to address the prevailing burden of oral health issues adequately. The limited number of oral health professionals poses challenges in terms of the timeliness, frequency, and reliability of delivering oral health education and instructions to patients. This situation often leads to a focus on providing curative treatments to patients experiencing pain and sepsis. However, it is crucial to emphasize the significance of oral health education in empowering individuals to engage in effective self-care practices at home. Oral health education is essential for the prevention of oral diseases and for guiding patients on the proper adherence to necessary treatments. The issue of limited access to health care has been

effectively tackled through the implementation of telemedicine, which enables remote consultations and the provision of medication prescriptions via mobile health applications[155].

Mobile health technology has been recognized as a highly promising and effective tool for disseminating crucial health education in resource-constrained regions and low-income countries[156]. The prevalence of mobile phone usage in Rwanda is substantial, as evidenced by a mobile phone penetration rate exceeding 80% among the population[157]. Mobile health interventions have been successfully implemented in Rwanda for other health issues, such as maternal and child health[158, 159]. In various regions, there have been notable advancements in the creation of mobile applications aimed at promoting oral health education. Research conducted in this field has indicated that these apps have demonstrated efficacy in enhancing individuals' understanding of oral health concepts and fostering positive oral hygiene behaviours[160].

The Government of Rwanda has made a commendable effort to allocate additional resources towards the advancement of information communication technology (ICT) in order to enhance the efficiency and effectiveness of online health services delivery[161]. The implementation of online health consultation in Rwanda is a commendable step towards enhancing healthcare accessibility. This innovative approach allows patients to receive expert guidance and consultation from qualified health professionals through convenient phone calls. Moreover, it should be highlighted that Rwanda has launched an admirable program called Connect Rwanda. The primary objective of this initiative is to ensure that every household in the nation owns a smartphone, thereby enabling easy access to online services. As a result, a substantial number of Rwandan citizens have already received smartphones, allowing them to access a wide range of online resources [56]. Nonetheless, it is important to acknowledge that there are still existing deficiencies in the dissemination of online oral health education and information within communities. The utilization of oral health applications to improve patients' self-care practices at home holds promise in reducing the prevalence of oral diseases in Rwanda.

2.5.5 Acceptability of mobile App in health education

Acceptability of the use of a new intervention is important to show how user-friendly and useful the intervention will be. Acceptability refers to the degree to which somebody agrees that something is good enough to use[162]. The participants in a study conducted in Boston showed a

significant level of acceptance for the mobile oral health App, with 73.7% of them expressing their approval[163]. Among the participants in Malaysia, a reported acceptability rate of 77% was observed[163, 164]. According to a study conducted by Venkatesh et al., the mobile App which found to be highly acceptable, indicating a strong intention to be used by participants[165]. The mobile App's low acceptance can imply a lack of popularity, and it has been noted that this can impact its utilization[166]. The mobile App's exceptional acceptability is praiseworthy since it has led to frequent utilization of the App in various environments[167]. The Technology Acceptance Model states that consumers' attitudes towards and intentions to utilize a technology are influenced by their perception of how easy it is to use[168]. A study by Davis et al. has demonstrated that individuals are more inclined to embrace technologies that are viewed as user-friendly[169]. According to the Authors, people who use oral health applications on their mobile devices are highly enthusiastic about promoting and discussing their experiences, and they actively encourage others to use the program. The enthusiasm is mainly because of its user-friendly interface[170]. A study conducted in Massachusetts reported that all participants expressed agreement that the app was user-friendly and easy to operate[171].

2.5.6 Feasibility of mobile App in health education

Feasibility of the use of a new intervention is important to curb the wastage of resources that could occur in the full roll-out of the activity. Feasibility refers to how easy or difficult it is to do something [172]. Prior to implementing a program, it is essential to assess its feasibility as one of the earliest stages. Nicholas and Chinedum emphasize the significance of feasibility determination in assessing the potential success of a proposed program, project, service, or business. Feasibility determination is needed for the growth of the programme to advocate for its continuance [173]. In a study conducted among adults, it was shown that mobile-based video education programs had beneficial benefits as it found to be successful in improving patients' knowledge by ultimately enhanced the dental health of the participants[174]. The research emphasizes the efficacy of multimedia interventions, such as films, in facilitating health education and fostering changes in behaviour [175]. The movies undoubtedly functioned as helpful pedagogical resources, offering visual illustrations of correct oral hygiene practices and augmenting participants' comprehension of dental care skills. Mobile applications for oral health education are beneficial for individuals of all ages, including adults, adolescents, and children. It has been demonstrated that the information delivered via smartphones by parents has a favourable influence on children's awareness of oral

health[176, 177]. The mobile Apps that are found to be useful should be promoted, and their messages should be designed according to the end users. In addition, the content should be theoretically grounded and empirically validated[178].

2.6 OBJECTIVE, GAPS AND CONTRIBUTION OF THE PHD

The table below summarises the identified gaps in the literature and the contribution of the PhD in addressing some of the gaps (Table 2.1).

Table 2. 1 Objective, knowledge gaps and contribution of the PhD

Study Objective	What is known	Knowledge Gaps	Scholarly contribution of the PhD
To determine the oral health knowledge, attitude, and oral hygiene practices (KAP) in the rural and urban areas in Nyarugenge District, Rwanda.	- Global prevalence estimates - Prevalence oral disease - K-A-P educational theory[74]	Dearth of studies on the oral health KPA in Rwanda	Manuscript on K-A-P in Rwanda: “Oral health knowledge, attitude and oral hygiene practices among adults in Rwanda”
To evaluate oral health services in Nyarugenge District	Lack of instruments had been reported in several settings	The lack of comparative analysis of the healthcare facilities for the provision of preventive oral health services offered in Nyarugenge District.	This is amongst the first audits to assess oral health services and evaluate perceptions of oral health professionals when rendering oral health services in Rwanda.
To explore perceptions of oral health professionals in rendering oral health services to the community of Nyarugenge District	Oral health professionals faced many challenges while offering oral health services to the community.	Lack of studies on the challenges facing oral health professionals in rendering oral health services in Nyarugenge District.	“Evaluation of oral health services and perceptions of oral health professionals working in Nyarugenge, Rwanda”
To assess the feasibility and acceptability of using mobile App for oral health education in Nyarugenge District of Rwanda.	The mobile App in health sectors had been found to promote better health outcome.	Lack of study on feasibility and acceptability of mobile App for oral health education in Rwanda.	- This is amongst the first studies on feasibility and acceptability of mobile App for oral health education in Rwanda. - The study revealed that the mobile App for oral health education (BrushDJ was highly acceptable and feasible among the participants. “The Feasibility and Acceptability of a Mobile App for Oral Health Education” Among Adults in Rwanda”

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CHAPTER 3

Methodology

This mixed methods PhD study has combined quantitative and qualitative research methods, which are summarised in this chapter. The chapter is divided into four sections: Section 3.1 describes the conceptual framework used in the study. Section 3.2 the cross-cutting methodological elements: the study setting, study design and the ethical considerations and approvals. Section 3.3 specific methodological approach per study objective and Sections 3.4 summarise study limitation.

3.1 THE CONCEPTUAL FRAMEWORK

The ecological model was used to address the objectives of this thesis. The model shows that better oral health outcomes in the community depend on several factors with a multi-level approach to maintain better oral health. The study proves that patient empowerment with better oral health knowledge, attitude and practices could play a big role in promoting better outcomes. Even though patients could have better oral health behaviours and adequate oral health knowledge to support their practices, patients should be motivated to visit services for regular checkups and get appropriate treatment. However, if there are inadequacies in dental services, including a lack of instruments and insufficient infrastructure necessary to support the provision of dental services to patients, then patients may not receive proper treatment. The inadequacies could result in a lack of trust on the patients' part, potentially leading to a decrease in the good oral health behaviours they have developed. In addition, oral health professionals need to be supported and work in the optimal workplace without challenges to offer quality care to the community. Finally, the use of mobile applications for oral health education could result in better oral health outcomes and motivate patients to engage in better oral health behaviour by improving their oral health knowledge, attitudes, and practices.

The ecological model posits that five factors influence behaviour interdependently. The intrapersonal factors, such as biological and psychological factors; organisational factors comprise health system factors; interpersonal factors, such as social support from friends or family members; community encompasses cultural factors or norms and policy influence the behaviour of interest[1]. This model was applied in the study to ascertain the relationships and the contributing

factors to oral health behaviour. Oral health behaviour and practices will depend on multiple levels, as indicated in Figure 3.1, the proposed conceptual framework of this PhD.

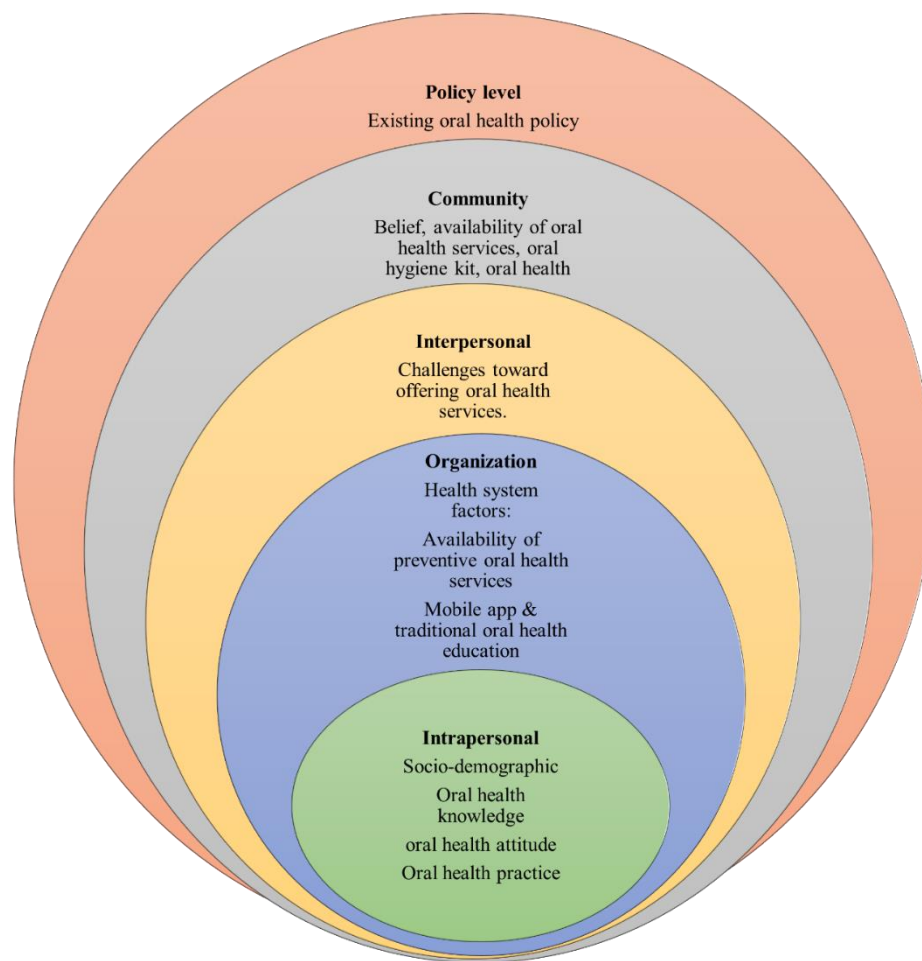


Figure 3. 1 Conceptual Framework: Ecological model

Source: [4].

The conceptual model is guided by an ecological model, even though different theories explain health behaviours. The theories of behaviour include but are not limited to social cognitive theory, stages-of-change theory, and ecological theories. Social cognitive theory assume that an individual's attitudes and beliefs influence health behaviours [2]. Stage-of-change theory assume that individual attitudes and beliefs influence health behaviour, but behaviour change occurs

through different stages[2]. The social cognitive and stage-of-change theories consider individuals to be the sole predictors of health behaviours. However, individuals need some skills and support to adopt a specific behaviour. This support can be in different forms, such as social, psychological, environmental, and political. This interdependence between individuals and the environment in explaining health behaviour gives rise to an ecological model of health behaviours.

The ecological model that guides the thesis is a theory-based framework for identifying the multi-layered and interactive effects of environmental and personal factors that govern behaviours or practices[3]. It was initially introduced as a conceptual model for understanding human development by psychologist Urie Bronfenbrenner in the 1970s and then formalised as a model in the 1980s[4]. The model suggests that individual factors, like biological and psychological aspects, interpersonal dynamics such as support from friends or family, organisational elements within the health system, community norms and cultural factors, and policy all play a role in influencing the behaviour under consideration [1].

Description of the conceptual framework

In order to achieve better oral health outcomes, a number of different elements, including those at the intrapersonal(individual), interpersonal, community, organisational, and policy levels, play critically important roles[4, 5].

Intrapersonal (Individual) Factors: In oral health, individual factors such as genetics, oral hygiene practices and oral health outcomes[6]. Individual behaviours, attitudes, and beliefs surrounding oral health also play a crucial role in shaping oral health status[7].

Organisation factors: organisation factors in this study refer to the availability of preventive oral health care, traditional oral health education and the availability of mobile oral health Apps.

Interpersonal Relationships: Social networks, family dynamics, and cultural norms surrounding oral health behaviours impact an individual's oral health status. Supportive social relationships and community networks among oral health professionals can contribute positively to better oral health outcomes in the community.

Community Factors: Availability and access to affordable dental care are significant determinants of oral health. Additionally, available oral hygiene kits and oral health services in the community play a crucial role.

Policy and Healthcare Systems: Policies, regulations, and healthcare systems that support oral health promotion, prevention, and treatment play a vital role in improving oral health outcomes. Access to dental insurance, public health initiatives, and workforce policies affecting the recruitment and availability of oral health professionals also impact oral health. Well-equipped dental health facilities promote better oral health outcomes.

3.2 CROSS-CUTTING METHODOLOGICAL ELEMENTS

3.2.1 Study setting

This research was conducted in Nyarugenge District, Kigali City, Rwanda (Figure 3.2). Rwanda is one of the 56 countries in the continent of Africa. Rwanda is divided into four provinces, plus Kigali City, the capital city. The four provinces have 27 Districts, while Kigali City has three districts (Gasabo, Kicukiro, and Nyarugenge) based on Government data[8, 9]. According to the fourth population and housing census in 2012, Nyarugenge district has the highest population density, with 2,149 inhabitants/km² in Kigali City and 284,561 inhabitants. Nyarugenge District has ten sectors, and each sector has a health facility[8]. There are seven public health facilities that provide dental services, these are: five health centres (HC), one district hospital and a University teaching hospital that provides dental services in Nyarugenge District. Health facilities which do not have dental services were excluded[8].

1. Biryogo HC
2. Cor-Unum HC
3. Kabusunzu HC
4. Nyarurenzi HC,
5. Kanyinya HC)
6. The University Teaching Hospital of Kigali (CHUK)
7. Muhima District Hospital

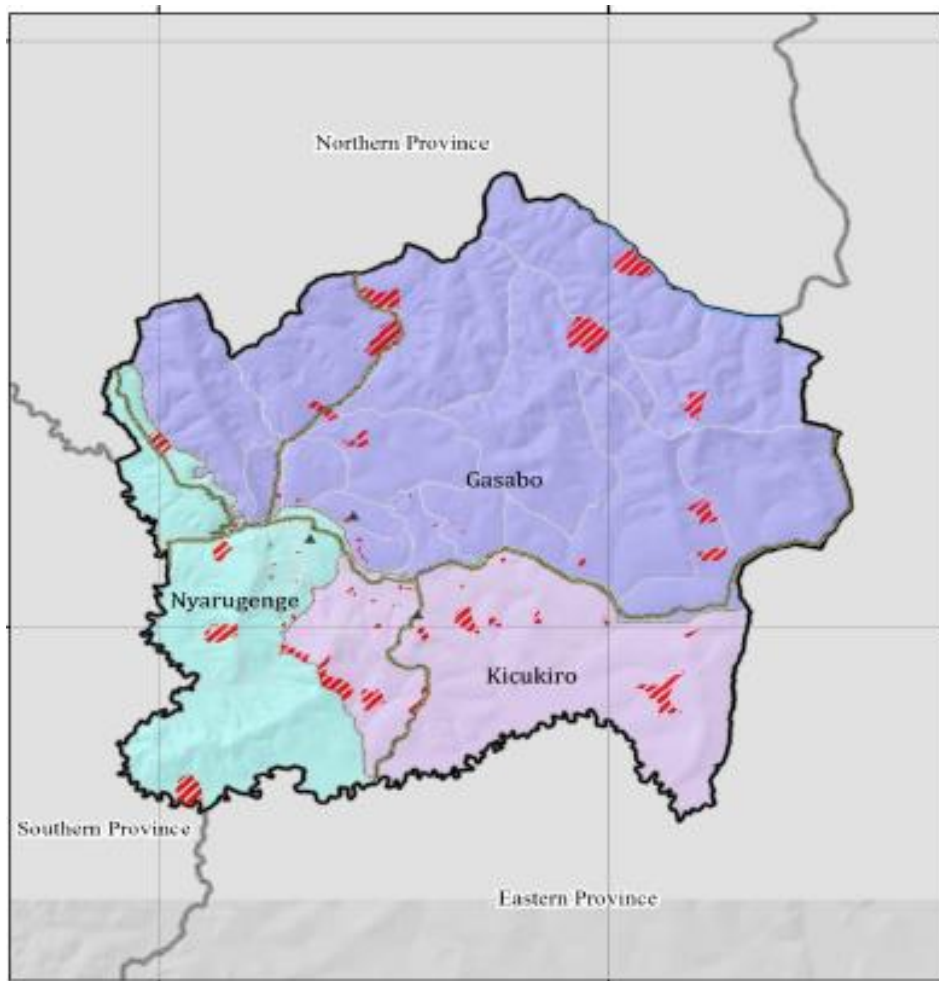


Figure 3. 2 Map of Kigali city.

Source: [10]

3.2.2 Study design

A concurrent mixed-methods study design, consisting of quantitative and qualitative research methods was used. Four distinct but interlinked studies were conducted to address the objectives of this PhD study.

Part 1: Quantitative

Objectives 1, 2, and 4 of the study were measured using a quantitative approach (Table 3.1). A cross-sectional quantitative study design was used to assess the knowledge, attitude, and oral hygiene practices among adults in Nyarugenge District, Rwanda. Furthermore, an audit of oral health services in Nyarugenge District was conducted. Lastly, a cross-sectional quantitative survey was used to assess the feasibility and acceptability of the mobile App for oral health education.

The cross-sectional approach was used for the objectives of the PhD due to its capability to provide a view of the population at a specific point in time without the need for longitudinal follow-up.

The cross-sectional approach is quick and cost-effective as the data is collected from all participants at one time point, reducing the time in data collection and resources required. Cross-sectional studies are typically used to determine how common a particular outcome is within a specific population, often to aid in public health planning. These studies are hypothesis generating and gather data on individual traits, such as exposure to risk factors, along with details about the outcome itself. Thus, cross-sectional studies offer a momentary view, capturing both the outcome and associated characteristics at a specific moment[11].

Part 2: Qualitative

Objective 3 of the study was assessed using an exploratory qualitative approach (Table 3.1). The qualitative approach was used to explore the perceptions and experiences of oral health professionals when offering oral health services to the community of Nyarugenge District.

3.2.3 Ethical considerations

The Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand, Johannesburg, provided ethics approval (M220213) to conduct the research (Appendix 1). Permission was also obtained from the relevant healthcare authorities, the Rwanda IRB Ethical Committee (No234/CMHS IRB/2022) (Appendix 2), and the National Health Research Committee (No NHRC/2022/PROT/26) (Appendix 3). The permission to collect data in the public health facilities was obtained from the Ministry of Health Rwanda. The participants were informed of the purpose of the study (Appendix 4,5,6), and informed consent was sought from all participants (Appendix 7,8). There was no coercion, and participants were given the opportunity to withdraw from the study at any time without prejudice regarding continuing care. Confidentiality and anonymity were maintained throughout the study. COVID-19 protocols were provided for the study since the protocol approval was received during the pandemic period 2020-2022; however, at the time of data collection in 2020, measures were respected to ensure the safety of the participants(Appendix 9)[12].

The ethical considerations that were considered and the corresponding actions taken to address them are described as follows:

- Prior to participating in the study, participants were provided with clear and comprehensive information regarding the purpose, procedures, risks, and benefits of their involvement.
- Informed consent forms were distributed and signed to ensure that participants understood their rights, including voluntary participation, confidentiality, and the right to withdraw from the study at any time without penalty.
- Confidentiality measures were implemented to protect the privacy of participants and ensured that sensitive information shared during the study remained secure and anonymous.
- Data collection protocols were designed to minimise the collection of personal identifiable information and to store data securely using encryption, password protection, and restricted access only to the principal investigator.
- The participants had a right to make informed decisions about their involvement, and participants were respected throughout data collection.
- Research procedures were conducted in a manner that minimised discomfort, coercion, or undue influence on participants, and measures were taken to ensure that participants could freely express their views and experiences without fear of reprisal or judgment.

3.3 SPECIFIC METHODOLOGICAL APPROACH BY STUDY OBJECTIVE

This PhD thesis consisted of four distinct but interlinked study components based on the objectives described in Chapter 1. Each study will be described briefly and further explained in the respective Chapters 4 -7 that follows.

Study 1: Oral health knowledge, attitude, and oral hygiene practices among adults in Nyarugenge District, Rwanda

Study 2: Evaluation of oral health services in Nyarugenge District

Study 3: Exploring the perceptions and experiences of oral health professionals in rendering oral health services to the community of Nyarugenge District

Study 4: Assessing the feasibility and acceptability of using mobile App for oral health education in Nyarugenge District of Rwanda.

3.3.1 Study 1

Oral health knowledge, attitude, and oral hygiene practices among adults in Nyarugenge District, Rwanda

Study population

Adult patients aged 18 years old and above attending the three randomly selected dental health clinics from the seven dental health clinics in Nyarugenge District were recruited.

Sampling technique

The seven urban health facilities with dental services in Nyarugenge District were randomly sampled to obtain three health centres. The participants were selected conveniently from the three health centres (Biryogo HC ; Cor-Unum HC; ; Nyarurenzi HC). The use of convenient sampling made the research process more efficient due to the reduction of time required to recruit participants, and whoever came on-site was recruited to be part of the study.

Sample size calculation

The sample size was calculated based on the estimated oral health knowledge prevalence of 50%, with a 95% confidence level and a 5% level of precision of 420[13]. The sample size was determined using a statistical formula proposed by Danial[13, 14]. A **z** score of 95% confidence level equals 1.96, a relative precision of 5%(**d**), expected prevalence (**p**), and **n** is a sample size.

$$n = \frac{z^2 p(1-p)}{d^2} \quad n = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = \frac{0.9604}{0.0025} = 384 \text{ Participants}$$

The total sample size of 384 participants plus 10% (38 participants) of the non-response rate was required to maintain the precision, power, and representativeness of the study. The total sample size was 422 participants.

Inclusion criteria

Participants who were present on the day of data collection, consented and demonstrated cognitive clarity were enrolled in the study.

Exclusion criteria

Hospitalised patients and mentally challenged patients were excluded due to their incapability to consent and to communicate during interviews.

Data measurement tool

The data collection tool (Appendix 10) was adapted from similar studies that assessed oral health knowledge, attitudes, and practices[15, 16]. The items were pilot tested among 15 participants the Cronbach alpha was approximately 0.7. The questionnaire had 39 multiple-choice questions categorised into four sections. Section A had ten questions related to the demographic characteristics of the participants. Section B had ten multiple-choice questions for assessing oral health knowledge. Section C had five Likert scale questions for assessing attitude toward oral health using a five-point Likert scale. Section D had 12 multiple-choice questions related to oral health practices.

Data collection process

Data was collected by the principal investigator (EN) and four research assistants who have dental backgrounds and adequate experience in collecting quantitative data. Four research assistants were trained by the principal investigator before data collection. The 422 adult patients were recruited from three health centres using convenient sampling. The participants were recruited in the waiting room at the reception before treatment, and others were recruited after treatment. The participants who agreed to participate in the study were given a participant information sheet (Appendix 4) regarding the purpose of the study and following the signing of the informed consent (Appendix 7), they were included in the study. Each participant was given a unique number for anonymity and was interviewed for 30 minutes in Kinyarwanda's local language using an interviewer-administered structured questionnaire. Then, their responses were written in Google form.

Data analysis

The Stata software version 16 was used for analysis (StataCorp, College Station, TX). Descriptive statistics frequency and percentage distribution were used to analyse demographic characteristics, oral health knowledge, oral health attitude, and oral hygiene practice. Bivariate and logistic

regression was done to assess factors associated with oral health knowledge, oral health attitude and oral hygiene practices. The significance level was set at 0.05 with a 95% confidence interval.

The oral health knowledge questions were analysed by assigning the correct answers a score of “1” and the wrong answers and did not know a score of “0”. The oral health knowledge was summed up to 100%. A score of less than 60% was classified as ‘poor oral health knowledge’, and a score of 60% and above indicated ‘good oral health knowledge’.

The oral health attitude questions were analysed by allocating the positive attitude a score of “1” and the negative attitude a score of “0”. In contrast, neutral responses were not allocated any score and were not used in computing the total attitude score. The attitude responses were summed up to 100%. An attitude score of less than 60% indicated a poor oral health attitude, and a score of 60% and above showed a good oral health attitude. In addition, the responses of attitudes “strongly disagree” and “disagree” were combined to “disagree” and “strongly agree” and “agree” were combined and became “agree”, and neutral responses were reported in the frequency tables.

Oral hygiene practice questions were analysed by allocating the correct answers a score of “1” and the wrong answers a score of “0”. The responses' scores were summed up to 100%. A score of less than 60% was categorised as ‘poor oral hygiene practices’, and scores of 60% and above indicated ‘good oral hygiene practices’.

3.3.2 Study 2

Evaluation of oral health services in Nyarugenge District

Study population

The seven public dental health facilities in Nyarugenge District were audited. Each health facility was given a unique code for anonymity.

Sample size

No sampling was done; all seven public dental health facilities in Nyarugenge District were included in the audit.

Data measurement Tool

The data collection tool (Appendix 11) was adapted from a previous study conducted by Josephine et al. in 2018 in Zambia[17]. The checklist items had three sections for assessing the availability and adequacy of oral hygiene services and functionality of dental equipment. The meaning of availability in this research refers to the presence of materials or equipment in the dental setting. Functionality refers to the instruments and equipment being able to perform their intended function or purpose effectively and efficiently. Adequacy refers to being sufficient in quantity. Essential equipment included in the checklist were a dental chair, dental light, dental stool, dental compressor, suction lines, and Benchtop sterilising unit. Diagnostic instruments included were dental trays, mouth mirrors, explorers, and periodontal probes. Instruments for scaling and polishing included in the checklist were an ultrasonic scaler unit, ultrasonic scaler tips, a manual scaling set, suction tips, and a prophylaxis cup. Lastly, the tool also appraised the personal protective equipment. The availability and adequacy of essential dental materials for polishing, such as prophylaxis paste, and then the checklist also contained oral hygiene aides for oral health education, such as dental models, toothbrushes, dental floss, and specific mobile Apps for oral health education.

Data collection process

The principal investigator and one research assistant (dental therapist) collected data using observation methods to complete the checklist items for auditing oral health services. If we did not see some materials or equipment due to the arrangement of dental facilities, we asked the oral health professional on site to show us the materials and equipment needed to ensure that we got the right information.

Data analysis

Descriptive statistics were used to analyse the data using percentage and frequency distribution. The analysis used dichotomous responses, one equal to ‘yes’ and zero equal to ‘no’, to identify the availability, adequacy, and functionalities of the dental facilities. The Stata version 16 was used to analyse data.

3.3.4 Study 3

Exploring the perceptions and experiences of oral health professionals in rendering oral health services to the community of Nyarugenge District

Study population

Nyarugenge District has fourteen oral health practitioners distributed as follows: Five dental therapists, each working in one of the five health centres; three dental therapists who work in the District hospital; three dental therapists and three dentists who work in referral hospitals.

Sample size

All oral health professionals rendering oral health services in seven public dental health facilities in Nyarugenge were recruited for the in-depth interviews (IDIs). All fourteen oral health professionals were recruited, and all consented to participate in the IDIs.

Data collection: Interview Guide

The interview guide (Appendix 12) was adapted from a previous study conducted by Josephine et al. in 2018 in Zambia[17]. The interview guide had 12 questions for obtaining qualitative data regarding various perceptions and experiences of oral health professionals in providing oral hygiene services to the community. The questions used in the interview guide explored the following. Firstly, it explored the perceptions and experiences of oral health professionals regarding their work, including their satisfaction level, workload, and any challenges they face in managing patient care efficiently. Then explored any challenges faced by oral health professionals in providing oral health education to every patient, with considerations of time constraints or other obstacles that may hinder their practice. The ability of oral health professionals to provide scaling and polishing treatments to all patients in need, including the volume of patients requiring such treatments and any barriers encountered, were also explored. The interviews probed further about any challenges related to sterilising instruments used for scaling and polishing procedures; the availability of time to provide oral hygiene instructions to patients was asked. The oral health professionals were asked to reflect on the quality of treatment provided to patients and the satisfaction level with the care delivered, the contingency plans and procedures when equipment in the dental clinic malfunctions or requires repair. Management of dental materials such as polishing paste, including protocols for replenishing supplies when they run out. Considerations

for safety during treatment, including concerns about contamination risks and the availability of personal protective equipment like masks, gloves, sleeves, and eyewear. Insights into potential strategies to reduce workload based on their experiences and observations. Suggestions for enhancing oral hygiene treatment within dental clinic facilities aimed at improving patient care outcomes. Recommendations to streamline and improve their work environment to make their job easier and more efficient were also explored.

During the interviews, probing was done for each question to understand and capture the participants' deep perceptions and thoughts. The use of in-depth interviews provides a deeper investigation into individual experiences and viewpoints, especially in situations where sensitivity or thorough comprehension is crucial. The use of in-depth interviews in this research allowed each participant to freely express their thoughts, emotions, and personal experiences without the impact or dynamics of group interactions. Participants' views needed to be independent and not influenced by their peers, managers or senior colleagues.

Data collection process

The participants were given an information sheet (Appendix 5) to help them understand the purpose of the study. Those who agreed signed an informed consent letter (Appendix 8) before the in-depth interviews (IDIs). IDIs allow us to explore individual narratives and gain a comprehensive understanding of participants' viewpoints. The principal investigator and one research assistant conducted the in-depth interview. IDIs were conducted by appointment, in a private room or via phone call at the convenience of the oral health professionals. All IDIs were audio-recorded, and the research assistant kept notes. The IDIs were conducted in English and explained in Kinyarwanda, the local language, when necessary. Each interview lasted around 30 minutes. The responses of participants were translated, transcribed verbatim and saved as individual Microsoft Word documents soon after the interview.

Data analysis

After the transcription, the text was imported into NVIVO software for a detailed analysis. The interviews were analysed using thematic content analysis[18]. The process of thematic content analysis typically involves several stages: becoming familiar with the data collected, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing

the final analysis[18]. Two researchers and PI coded separately and later discussed the codes to keep and generate the final theme/s from the generated codes. The final approved themes regarding the perceptions and experiences were related to human resources, supply chain management, patient education and service rendering strategic management and administration.

To ensure trustworthiness, the team liaised to discuss the codes generated independently and to reach an agreement on the codes and themes. Additionally, trustworthiness during analysis was maintained by meeting the criteria of credibility, dependability, confirmability, and transferability [19]. Credibility refers to the accuracy and believability of the findings, interpretations, and conclusions drawn from the data [19]. To ensure credibility in this study, three researchers independently coded the data. Dependability was ensured by enhancing the study's replicability through a detailed explanation of the data collection procedure, including the interview guide questions, to ensure reliability. The repeatability was ensured by using methods that had been previously employed, with detailed documentation on data collection, coding, and analysis techniques. Confirmability refers to the objectivity and neutrality of the research findings, ensuring they are free from the influence or bias of the researcher[19]. This research achieved confirmability using purposive sampling to get the required data from participants who could provide the necessary data to answer research questions effectively, as well as independent coding and code generation from different researchers. Transferability refers to the extent to which the findings of a study conducted in one context can be applied or transferred by the reader to another context with similar characteristics or conditions. To ensure transferability, a clear description of the research context, including participants, the recruitment thereof, and study setting, has been provided. Additionally, the findings are presented in a detailed and nuanced manner[19].

3.3.5 Study 4

Assessing the feasibility and acceptability of using mobile App for oral health education in Nyarugenge District of Rwanda.

Study population

All adult patients aged 18 years and above who met inclusion criteria such as own a smartphone and being able to understand English or French were recruited from a larger study conducted across three health centres in Rwanda, which assessed oral health knowledge, attitudes, and practices

(KAP)[20]. The KAP study recruited 426 participants, and the sample was limited to respondents who were 18 years of age or older and residents of Nyarugenge District in Rwanda.

Sampling technique and Sample size calculation

Adult patients aged 18 years and above were recruited during data collection for the first objective, which assessed oral health knowledge, attitudes, and practices among 426 participants across three health centres in Nyarugenge District. The inclusion criteria to achieve this objective were owning a smartphone and understanding English or French. During recruitment, many participants were excluded (n=315) because they neither owned a smartphone nor understood English or French. All participants who accept to download the mobile App for oral health education were also included. Eventually, n=111 participants constituted the sample size.

Each eligible participant was assisted by a research assistant to download the mobile App for oral health education called BrushDJ [21] and subsequently received clear instructions on its usage following installation. If the participants agreed to get a BrushDJ mobile App for oral health education, the following question asked participants to record their mobile number for future contact on the assessment of the downloaded BrushDJ mobile App after three months. The 111 participants were recruited to test the acceptability and the feasibility of the BrushDJ mobile App for oral health education. There is no clear guidance on sample size calculation when one is conducting a feasibility study; the recommendation regarding total sample size varies, and no sample size calculation is needed[22].

Inclusion criteria

The included participants were those who owned a smartphone, understood English or French (as Rwanda use both English and French as official languages in education), accepted the disclosure of their mobile numbers for follow-up interviews, agreed to the downloading of the BrushDJ mobile App for oral health education, and willingly signed a consent form.

Exclusion criteria

The participants were excluded (n=315) because they did not meet the inclusion criteria above.

Data collection process

At the end of three months an online structured questionnaire (Appendix 13) was used to collect data. The group that used WhatsApp received the questionnaire (in English or French based on their preference) on their smartphone and filled in data in Google Forms. For those who did not use WhatsApp or were offline during time of data collection, data was collected using a telephone interview based on the questionnaire. Data was collected using a structured questionnaire (Appendix 13) adapted from reported studies [23-25]. Data collection tool consisted of 32 questions: three demographic questions, six on habitual oral health practices, ten questions for assessing acceptability, and 13 questions for assessing the feasibility of a mobile oral health App. The five-point Likert scale was used to assess the acceptability and feasibility of mobile App for oral health education. The five-point Likert scale was composed of: strongly disagree, disagree, neutral, agree and strongly agree, which ranged from one to five.

Data analysis

The Stata software version 16 was used for analysis (StataCorp, College Station, TX). Descriptive statistics, such as frequency and percentage distribution, were used to analyse the feasibility and acceptability of the BrushDJ mobile App for oral health education. Bivariate analysis using the Chi-square test was performed to measure the level of association between demographic characteristics and the mobile oral health App acceptability and feasibility. The significance level was set at 0.05 with a 95% confidence interval.

The Likert scale was used to assess the acceptability of the mobile App. Five responses were proposed to the participants, and they selected one among the following: strongly disagree, disagree, neutral, agree and strongly agree, which ranged from one to five. Reverse scoring was implemented on five questions to counteract response bias and ensure a balanced assessment across all items and then acceptability was analysed by combining ten questions on acceptability to obtain a total score of 50 (100%). A score less than 70% was classified as 'Less acceptable', and a score of 70% and above indicated 'Highly acceptable' [26].

Feasibility was also assessed using a similar Likert scale, and the analysis was done by combining 13 questions for feasibility to calculate a total score of 65 (100%). The values for each question ranged from one to five, and the given options were strongly disagreed, disagree, neutral, agree

and strongly agree. A score less than 70% was considered “Less feasible”, while a score of 70% and above was considered “Highly feasible”.

3.4 STUDY LIMITATIONS

One of our study's limitations is the use of a cross-sectional design, which cannot establish causality. However, we addressed this limitation by conducting a regression analysis that adjusted for confounding factors likely to influence the outcomes. The study's limitations were that participants were recruited from a specific district and exclusively from government institutions; therefore, the findings cannot be applied to the entire country or private facilities. Employing a simple random sampling to select health facilities in the Nyarugenge District health sectors and a large sample size may mitigate but not account for the private facilities. Another limitation the sample size and location do not represent the entire city, which limits the generalizability of the findings. The K, A,P was assessed using a validated tool from literature. The tool’s reliability it was thus not re-tested for reliability in the study setting. The tool was used and validated in a prior study and could have been tested for the current setting.

Table 3.1 provides an overview of study objectives, methods and data analysis.

Table 3. 1 Overview of the study objectives, methods, data collection tool and data analysis

Objectives	Study approach	Study sample	Sampling technique and sample size	Methods/ tools	Variables	Data analysis method(s)
1. Oral health knowledge, attitude, and oral hygiene practices among adults in Nyarugenge District, Rwanda	Quantitative: Cross-sectional study	Adult patients attending public health centres that have dental services in Nyarugenge District	The seven urban health facilities with dental services in Nyarugenge District were randomly sampled to obtain three health centres. The participants were selected conveniently from the three health centres. The sample size was calculated based on the estimated oral health knowledge prevalence of 50%, with a 95% confidence level and 5% level of precision to be 420.	Questionnaire	Independent/exposure variables: - Demographic characteristics Dependant/outcome variables: - Oral health practices - Oral health knowledge - Oral health attitude	Descriptive statistics: - Frequency distribution - percentage distribution Bivariate analysis: - Chi-square test - T-test - Logistic regression
2. Evaluation of oral health services in Nyarugenge District	Quantitative, Cross-sectional study	Dental facilities	All seven public health facilities that have dental services were selected.	Review form Checklist	Availability, functionality and adequacy of dental materials and equipment	Descriptive statistics
3. Exploring the perceptions and experiences of oral health professionals in rendering oral health services to the community of Nyarugenge District	Qualitative exploratory design	The dental therapists and dentists offering services in the selected public hospitals	Purposive sampling – to select all oral health professionals in seven public health facilities n=14	In-depth interviews	Perceptions Experiences	Thematic content analysis
4. Assessing the feasibility and acceptability of using mobile App for oral health education in Nyarugenge District of Rwanda.	Quantitative: Cross-sectional study	Adult patients attending public health facilities in Nyarugenge District	Adult patients aged 18 years and above were recruited from a large study conducted across three health centres in Nyarugenge District, which assessed oral health knowledge, attitudes, and practices among 426 participants. During recruitment, some participants were excluded (n=315) because either they did not own a smartphone, they did not sign the informed consent, or they were not able to understand English or French. Eventually, 111 participants constituted the sample size.	Questionnaire	Dependent variables Feasibility Acceptability Independent variables Age Level of education	Descriptive statistics: Descriptive statistics: - Frequency distribution - percentage distribution Bivariate analysis: - Chi-square test

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RESULTS SECTION

This section presents the results of this PhD that were obtained to answer the study objectives. The research conducted for this PhD aimed to assess oral health and the role of using a mobile application for oral health education in Nyarugenge District of Rwanda. The three published articles generated from the PhD work are presented in three chapters (Chapters 4 - 6). Slight modifications have been made from the published manuscripts, such as the removal of acronyms that have already been introduced and the removal of journal-specific requirements, such as conflict of interest statements. Otherwise, they are presented as published from the specific journals.

Emmanuel Nzabonimana, Yolanda Malele-Kolisa, Phumzile Hlongwa. Oral health knowledge, attitude and oral hygiene practices among adults in Rwanda. <https://doi.org/10.11604/pamj-cm.2024.14.4.42461> (Appendix 14)

This first paper discusses adults' oral health knowledge, attitudes, and oral hygiene practices in Rwanda. Paper one employs a quantitative approach to get the current status of the community-level oral health knowledge, attitudes and oral hygiene practices. A descriptive cross-sectional study was done among participants attending public health facilities in Nyarugenge District, Rwanda. Participants were interviewed using a structured questionnaire. The findings of our study showed that almost half of the participants had poor oral health knowledge. Oral health attitude and oral hygiene practices were also lacking.

The people in the community should be empowered and get oral health support from the facility. To find a link, we audited oral health services and figured out the challenges that dental professionals face while offering oral health services to the community (paper 2) after getting the current status of the participants in the community, more information in below.

Emmanuel Nzabonimana, Yolanda Malele-Kolisa, Phumzile Hlongwa. Evaluation of oral health services and challenges facing oral health practitioners working in Nyarugenge, Rwanda. <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0309127> (Appendix 15)

This paper 2 provides insight into oral health services and challenges facing oral health practitioners working in Nyarugenge district of Rwanda. A cross-sectional concurrent mixed methods study was used. The quantitative and qualitative parts were independent during data collection and analyses and merged during the interpretation phase. To explore the challenges, we used qualitative approach methods and quantitative approaches to get the list of items available and functional at the health facility. The most significant challenges oral health practitioners face are low dental practitioner/patient ratios, lack of adequate and appropriate equipment and materials, patients' lack of oral health awareness, and a lack of administrative support. Well-established community preventive interventions, such as a dental mobile app, could reduce the patient/provider ratio by increasing population awareness of oral health and encouraging healthy behaviours. The findings in paper 2 revealed that oral health professionals are faced by challenges regarding human resources and a high number of patients load. These challenges were reported to make it almost impossible for them to give health education to every patient attending health services. The findings highlighted the high patient ratios that the oral health professionals found themselves with and the lack of time, materials and equipment to give oral health education. To address the lack of time to give oral health education to every patient, we assessed the feasibility and accessibility of the mobile App for oral health education, which is reported in paper 3.

Emmanuel Nzabonimana, Yolanda Malele-Kolisa, Phumzile Hlongwa. The Feasibility and Acceptability of a Mobile App for Oral Health Education Among Adults in Rwanda.

<https://www.dovepress.com/the-feasibility-and-acceptability-of-a-mobile-application-for-oral-hea-peer-reviewed-fulltext-article-CCIDE> (Appendix 16)

This paper 3 provides an overview of the feasibility and acceptability of a mobile App for oral health education among adults in Rwanda. A descriptive cross-sectional study was used. A total of 111 adult participants received the BrushDJ mobile App for oral health education and used it for three months. The mobile App for oral health education (BrushDJ) was highly acceptable and feasible among the participants. The mobile App for oral health was appreciated because it is user-friendly and clearly guides oral hygiene procedures with various well-integrated functions. Our study findings have highlighted that the mobile App for oral health (BrushDJ) is a useful tool that might contribute to behaviour change and the adoption of adequate oral health measures. Population groups of all ages and backgrounds, even those in remote areas where the accessibility to dental services is challenging, can use the mobile App for oral health education. However, there is a need to test its effectiveness on a larger population since our study only found the Apps to be feasible and acceptable by the community.

CHAPTER 4

Oral Health Knowledge, Attitude and Oral Hygiene Practices Among Adults in Rwanda

4.1 BACKGROUND

Oral diseases (OD), commonly tooth decay and periodontal disease are a major public health problem with 3.58 billion people reported to have tooth decay, according to the Global Burden of Disease report conducted in 2015[1]. Periodontal diseases are prevalent in developed and developing countries and affect about 20-50% of the global population[2]. Some studies have found a strong association between poor oral hygiene and common dental diseases such as dental caries and periodontal diseases[3, 4]. Globally, the burden of oral disease is high among older people and has a negative effect on their quality of life[5]. Poor oral hygiene causes tooth loss, which leads to disability and compromised patients' oral health [6].

In Africa, OD are a significant public health problem[7]. The prevalence of dental caries has increased in many African countries and may further increase due to increased sugar consumption and inadequate exposure to fluorides[7]. The prevalence of gingival inflammation is high in all age groups in several African countries[8]. In a study from Sudan, about 64.5% of participants considered poor tooth brushing habits to cause gingivitis and less than 20% of adolescents visit dentists regularly for a dental check-up[9]. In Tanzania, a study found that 44.8% of the participants had fair to poor oral hygiene status [10]. A study conducted in Ugandan study found that 56% of participants had not visited oral health services in the last two years, and those who did were due to pain[11].

In Rwanda, OD are among the leading cause of morbidity at the health centre level, with poor oral hygiene, tooth decay and periodontal disease, have been reported [12-14]. The Rwanda National Oral Health Survey in 2018 found that oral health status of the population was poor, with 70% of individuals not utilising oral health services. Adults aged 20 years and above from Rwanda have been reported to present with oral debris, and dental calculus[14].

Studies have associated low health literacy with greater use of emergency care and poor preventive health-seeking behaviour for oral health services [15, 16]. A correlation between limited oral health knowledge and poor oral health behaviour has been reported [17], however, there is scarcity

of information on oral health awareness levels in Rwanda. Therefore, this study evaluated knowledge, attitude, and oral hygiene practices among adults in Rwanda. It is part of a large doctoral study entitled "Oral health in Nyarugenge District of Rwanda: The role of mobile application in oral health education."

4.2 METHODS

4.2.1 Study design and setting

A descriptive cross-sectional study was conducted among participants attending public health facilities in Nyarugenge District, Rwanda. Rwanda stands as one of the 56 countries in the African continent. Rwanda is divided into four provinces, plus Kigali City, the capital city. The four provinces have 27 Districts, while Kigali City has three districts (Gasabo, Kicukiro, and Nyarugenge) based on Government data[18, 19]. The study was conducted in July 2022 in Nyarugenge District, Kigali City, Rwanda

4.2.2 Study population

Adult patients aged 18 years and above attending health services in Nyarugenge District were recruited for the study. Participants who voluntarily agreed and signed informed consent to participate were included in the study. Patients who were hospitalised and mentally challenged were excluded from the study. The seven urban health facilities services in Nyarugenge District were randomly sampled to obtain three health centres. The participants were selected conveniently from the three health centres. The sample size was calculated based on the estimated oral health knowledge prevalence of 50%, with 95% confidence level and 5% level of precision to be 420 participants[20].

4.2.3 Data collection

Data was collected by principal investigator (EN) and four research assistants who have dental background with adequate experience in collecting quantitative data. The participants were recruited conveniently and those who consent were interviewed in Kinyarwanda local language using a structured questionnaire which was adapted from previous reported studies[21-23]. The questionnaire elicited the demographic characteristics, oral health knowledge, oral health attitude and oral hygiene practices of the participants.

4.2.4 Definition

Outcome variable: oral health knowledge, oral health attitude and oral hygiene practices.

Exposure variable: Demographic characteristics (Age, gender, marital status, owning smartphone and level of education)

4.2.5 Statistical analysis

The Stata software version 16 was used for analysis (StataCorp, College Station, Tx). Descriptive statistics frequency and percentage distribution were used to analyse demographic characteristics, oral health knowledge, oral health attitude and oral hygiene practice. Bivariate and logistic regression was done to assess factors associated with oral health knowledge, oral health attitude and oral hygiene practices.

The oral health knowledge questions were analysed by assigning the most correct answer a score of "1", and wrong answers and don't know a score of "0". The nine statements on knowledge were summed up to a total score of 9, equivalent to 100%. A score less than 60% was classified as 'poor oral health knowledge' and a score of 60% and above indicated 'good oral health knowledge'.

The oral health attitude questions were analysed by allocating the positive attitude a score of "1" and negative attitude a score of "0" while neutral responses was not allocated any score and not used in computing the total attitude score. The attitude responses were summed up to a total score of 7 indicating 100% good attitude. The attitude score of less than 60% indicated poor oral health attitude and the score of 60% and above showed good oral health attitude. In addition, the responses of attitudes "strongly disagree" and "disagree" were combined to "disagree" and "strongly agree" and "agree" were combined and became "agree", and neutral responses were reported as it is in the frequency tables.

Oral hygiene practices questions were analysed by allocating the most correct answer a score of "1", and wrong answers a score of "0". The responses score was summed up to a total score of 8, indicating 100% good oral hygiene practises. A score of less than 60% was categorised as 'poor oral hygiene practices' and scores of 60% and above indicated 'good oral hygiene practices'.

4.2.6 Ethics consideration

The Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand, Johannesburg provided ethics approval (M220213) to conduct the research. Permission was also obtained from the relevant healthcare authorities, the Rwanda IRB ethical committee (No234/CMHS IRB/2022), and the National Health Research Committee (No NHRC/2022/PROT/26). Informed consent was signed by all participants.

4.3 RESULTS

4.3.1 Demographic characteristics of the participants

A total of 426 respondents participated in the study, with majority in the 18-27 years old age category (39.44%; n=168). The median age was 30, interquartile range (IQR) of 25 - 39. The majority of the participants, (61.50%; n=262) were female (Table 4.1).

Table 4. 1 Demographic characteristics of the participants

Demographic(n=426)	Frequency	Percentage
Age		
18-27 years	168	39.44%
28-37 years	129	30.28%
38-47 years	73	17.14%
48-57 years	34	7.98%
58-88 years	22	5.16%
Gender		
Male	164	38.50%
Female	262	61.50%
Marital status		
Single	136	31.92%
Married	271	63.62%
Divorced	12	2.82%
Other	7	1.64%
Participant own smartphone		
Yes	151	35.45%
No	275	64.55%
Level of education		
Primary	189	44.58%
Secondary	178	41.98%
University	31	7.31%
No education	26	6.13%

4.3.2 Oral health knowledge, attitude and practice

Poor oral health knowledge was found in 42.02% (n=179) of the participants. Oral health practices, 67.37%(n=287) and oral health attitude 12.44%(n=53) were also poor.

4.3.3 Frequency distribution of oral health knowledge among the respondents

Most of the respondents knew the importance of tooth cleaning, even though some had poor oral knowledge of the cause of gingival disease. The majority of the respondents 82.16% (n=350) knew the importance of cleaning between teeth in order to prevent gum inflammation. Most of the participants knew the importance of regular dental checkups 74.88%(n=319), while 25.12%(n=107) of the respondents did not know. Regarding tooth brushing 39.19%(n=397) of the respondents knew that tooth brushing should be done in the morning and at night daily (Table 4.2).

Table 4. 2 Frequency distribution of oral health knowledge

Oral health knowledge n=426	Yes n (%)	No n (%)	Don't know n (%)
To prevent tooth decay, I have to brush, especially on the crown covers of my teeth.	359 (84.27%)	36 (8.45%)	31 (7.28%)
Toothbrushing should be done in the morning after waking up and at night before going to bed every day.	397 (93.19 %)	22 (5.16 %)	7 (1.64%)
Dental plaque can cause gum diseases and tooth decay.	390 (91.55%)	12 (2.82%)	24 (5.63%)
Gum bleeding is a sign of gum disease.	376 (88.26%)	26 (6.10%)	24 (5.63%)
To prevent gum inflammation, you also have to clean between your teeth.	350 (82.16 %)	21 (4.93%)	55 (12.91%)
The hard deposit on your teeth can remove itself with toothbrushing alone.	213 (50.00%)	164 (38.50%)	49 (11.50%)
Bad breath can be caused by gum disease.	241 (56.57%)	97 (22.77%)	88(20.66%)
When my gum does not bleed while brushing my teeth, there is nothing wrong with my gum.	324 (76.06%)	60 (14.08%)	42(9.86%)
A regular dental check-up is necessary.	319 (74.88%)	89 (20.89%)	18 (4.23%)

4.3.4 Frequency distribution of oral health attitude among the respondents

According to the respondents' attitudes towards oral health, 56.19% (n=227) do not believe that teeth can be cleaned effectively without using toothpaste, while 43.81% (n=177) agree with this statement. Believe that dentists should be visited regularly, even without having an oral problem 23.66%(n=97) disagree, and 76.34 %(n=313) agree. Regarding oral health attitude on performing oral self-care regularly to identify any abnormality in my mouth, such as a hard deposit on my teeth, 3.33 %(n=14) disagree and 96.67%(n=406) agree as shown in Table 4.3.

Table 4. 3 Frequency distribution of oral health attitude

Oral health attitude n=426	Disagree	Agree	Neutral
Do you think the hardness of bristles of the toothbrush has an effect on teeth and gums.	29 (7.04%)	383 (92.96%)	14 (3.29%)
Do you think well-cleaning of teeth can be done without using toothpaste.	227 (56.19)	177 (43.81%)	22 (5.16%)
Do you think dentists should be visited regularly, even without having an oral problem.	97 (23.66%)	313 (76.34%)	16 (3.76)
Do you think you must perform oral self-care regularly to identify any abnormality in your mouth, such as a hard deposit on your teeth.	14 (3.33 %)	406 (96.67%)	6 (1.41%)
Do you think you cannot remove the hard deposit on your teeth with toothbrushing alone.	154 (38.79%)	243 (61.21%)	29 (6.81%)
Do you think waiting until you have toothache before visiting dentists can lead to tooth extraction.	93 (22.96%)	312 (77.04%)	21 (4.93%)
I think caring for my mouth is as important as caring for other parts of the body.	6 (1.44%)	412 (98.56%)	8 (1.88%)

4.3.5 Oral health practices among the respondents

Most respondents, 64.08%(n=273) brushed their teeth twice a day, while 35.9% brushed them once daily. The soft bristle toothbrush was used by 35.92%(n=153) respondents, while 21.13% (n=90) used a hard bristle toothbrush and 32.2% (n=137) and 3.05%(n=13) respondents visited dental services every six months. Most of the respondents 92.72% (n=395) had never used dental floss to clean their teeth, and only 0.94% 4(n=4) of the respondents used it twice daily, 2.11%(n=9) used it once a day and 3.52% (n=15) use dental floss sometimes and 0.7%(n=3) use once a week. (Table 4.4).

Table 4. 4 Oral health practice

Oral health practice		Frequency	Percentage
The method used to clean	Toothbrush and paste	422	99.06
	Finger	2	0.47
	None	2	0.47
When do you brush your teeth	Morning before breakfast	107	25.12
	Morning after breakfast	37	8.69
	Noon after lunch	5	1.17
	Night before going to bed	4	0.94
	Morning after breakfast and night before going to bed	273	64.08
The duration of brushing teeth	Less than 1 min	27	6.34
	One min	122	28.64
	Two min	88	20.66
	More than 2 min	176	41.31
	Do not know	13	3.05
Type of toothbrush used	Hard bristle	90	21.13
	Soft bristle	153	35.92
	Medium bristle	156	36.62
	Do not know	21	4.93
	Do not use toothbrush	6	1.41
The duration of replacing toothbrush	One month	121	28.40
	Three months	141	33.10
	Six months	20	4.69
	When the bristles are worn out	140	32.86
	I do not use a toothbrush	4	0.94
The type of motion used during brushing	Vertical strokes	31	7.28
	Horizontal strokes	276	64.79
	Circular motion	4	0.94
	Combination of the above	110	25.82
	I do not use a toothbrush	5	1.17
How often do you visit dental services?	Every 6 months	13	3.05
	Every 12 months	56	13.15
	Only when I have dental pain	220	51.64
	Never visited	137	32.16
Use of dental floss	Once a day	9	2.11
	Twice a day	4	0.94
	Sometimes	15	3.52
	Once a week	3	0.7
	Never	395	92.72

4.3.6 Frequency distribution of the reason for visiting dental services

The majority of the respondents 79.58% (n=230) among 289 who visited dental services in the past, had visited dental services due to pain, while 4.15% (n=12) respondents visited dental services for teeth cleaning, 5.54% (n=16) respondents visited dental services for oral check-ups and advice, 2.77% (n=8) visited dental services for gum problems and 7.96% (n=23) participants sought dental services due to gum problems.

4.3.7 The association between oral health knowledge, oral health attitude, oral health practices and demographic characteristics

Oral health knowledge was found to be significantly associated with oral health practices (P-value= 0.017), oral health attitude (P-value=0.000) and level of education (P-value=0.006). Owning a smartphone was found to be significantly associated with oral health knowledge (P-value=0.011), oral health attitude(P-value=0.049) and oral health practice (P-value=0.011) (Table 4.5).

Table 4. 5 Association between KAP and demographic characteristics

	Poor oral knowledge n(%)	Good oral knowledge n(%)	P value	Poor oral attitude n(%)	Good oral attitude n(%)	P value	Poor oral practice n(%)	Good oral practice n(%)	P value
Age group									
18-27 years	63 (35.2)	105 (42.51)	0.468	18 (33.96)	119 (40.34)	0.862	104 (36.24)	64 (46.04)	0.344
28-37 years	60 (33.52)	69 (27.94)		18 (33.96)	91 (30.85)		89 (31.01)	40 (28.78)	
38-47 years	29 (16.2)	44 (17.81)		10 18.87	50 (16.96)		53 (18.47)	20 (14.39)	
48-57 years	16 (8.94)	18 (7.29)		5 (9.43)	20 (6.78)		24 (8.36)	10 (7.19)	
58-88 years	11 (6.15)	11 (4.5)		2 (3.77)	15 (5.08)		17 (5.92)	5 (3.6)	
Total	179 (100)	247 (100)		53 (100)	295 (100)		287 (100)	139 (100)	
Gender									
Male	66 (36.31)	99 (40.08)	0.430	24 (45.28)	117 (39.66)	0.443	113 (39.37)	51 (36.69)	0.594
Female	114 (63.69)	148 (59.92)		29 (54.72)	178 (60.34)		174 (60.63)	88 (63.31)	
Total	179 (100)	247 (100)		53	295		287 (100)	139 (100)	
Own a smartphone									
Yes	51 (28.49)	100 (40.49)	0.011*	14 (26.42)	120 (40.68)	0.049*	90 (31.36)	61 (43.88)	0.011*
No	128 (71.51)	147 (59.51)		39 (73.58)	175 (59.32)		197 (68.64)	78 (56.12)	
Total	179	247 (100)		53 (100)	295 (100)		287 100	139 (100)	
Level of education									
Primary	97 (54.19)	92 (44.58)	0.006*	31 58.49	121 (41.30)	0.12	137 (47.74)	52 (37.96)	0.054*
Secondary	60 (33.52)	118 (48.16)		18 33.96	131 (44.71)		111 (38.68)	67 (48.91)	
University	11 (6.15)	20 (8.16)		2 3.77	26 (8.87)		18 (6.27)	13 (9.49)	
No education	11 (6.15)	15 (6.12)		2 3.77	15 (5.12)		21 (7.32)	5 (3.65)	
	179 (100)	245 (100)		53	293		287 (100)	137 (100)	
Oral health knowledge									
Poor knowledge	NA	NA	NA	32(60.38)	102(34.58)	0.000*	132(45.99)	47(33.81)	0.017*
Good knowledge				21(39.62)	193(65.42)		155(54.01()	92(66.19)	
Total				53(100)	295(100)		287(100)	139(100)	

*P-value≤. 0.5 statistically significant

4.3.8 Logistic regression for KAP and demographic characteristics of the respondents:

The variables found to be significant in the univariate analysis concerning oral health knowledge were marital status, smartphone ownership, and level of education. Oral health practices showed significant associations with smartphone ownership and level of education in the univariate analysis. In the multivariate analysis, individuals with a high school education were more likely to possess better oral health knowledge aOR=1.79, 95% CI 1.14; 2.82 and p-value 0.011 (Table 4.6).

Table 4. 6 Logistic regression for knowledge, attitude, practice and demographic characteristics

	Oral health knowledge				Oral health attitude				Oral health practice			
Factors	COR (95%CI)	P- value	AOR (95%CI)	P- value	COR (95%CI)	P- value	AOR (95% CI)	P- value	COR (95%CI)	P- value	AOR (95% CI)	P-value
Age	0.98 (0.97; 1.00)	0.09	1.00 (0.98; 1.02)	0.76	0.99 (.96; 1.01)	0.456	0.99 (0.96; 1.03)	0.83	.99 (0.96; 1.00)	0.14	0.96 (0.96 ; 1.01)	0.18
Gender												
Male	1.00		1.00		1		1		1		1	
Female	0.85 (0.57; 1.26)	0.430	0.95 (0.63; 1.45)	0.85	1.25 (0.69; 2.26)	0.44	1.32 (0.70; 2.48)	0.38	1.12 (0.73; 1.70)	0.59	1.07 (0.68; 1.67)	0.75
Marital status												
Single	1.00		1.00		1		1		1		1	
Married	0.61 (0.40; 0.94)	0.026*	0.62 (0.38; 1.03)	0.068	1.030 (0.54; 1.94)	0.927	1.074 (0.49 ;2.34)	0.856	1.21 (0.77; 1.89)	0.396	1.52 (0.90; 2.57)	0.11
Divorced	0.51 (0.15; 1.67)	0.267	0.51 (0.15;1.75)	0.287	0.35 (0.08; 1.57)		0.33 (0.06; 1.5)	0.162	1.2 (0.34; 4.21)	0.776	1.49 (0.40; 5.48)	0.545
Other	0.38 (0.08; 1.78)	0.222	0.40 (0.07; 2.00)	0.266	1				3.2 (0.68; 14.95)	0.139	5.07 (0.95; 26.85)	0.057
Own smartphone												
Yes	1.00		1.00		1		1		1		1	
No	0.58 (0.38; 0.88)	<u>0.011*</u>	0.68 (0.42; 1.09)	0.113	0.52 (0.27; 1.00)	<u>0.052</u>	0.67 (0.32; 1.37)	0.272	0.58 (0.38; 0.88)	<u>0.012*</u>	0.70 (0.43; 1.13)	0.147
Level of Education												
Primary	1.00		1.00		1		1		1		1	
Secondary	2.07 (1.35; 3.16)	<u>0.001*</u>	1.79 (1.14; 2.82)	<u>0.011*</u>	1.86 (0.99; 3.50)	0.053	1.67 (0.84; 3.31)3	0.143	1.59 (1.02; 2.46)	0.039*	1.44 (0.89; 2.31)	0.135
University	1.91 (0.87; 4.22)	0.106	1.49 (0.62; 3.54)	0.365	3.33 (0.74; 14.79)		2.38 (0.48; 11.64)	0.281	1.90 (0.87; 4.15)	0.107	1.40 (0.59; 3.31)	0.443
No education	1.43 (0.62; 3.29)	0.390	1.65 (0.70; 3.88)	0.250	1.92 (0.41; 8.84)		2.44 (0.50; 11.89)	0.268	0.627 (0.22;1.75)	0.373	0.62 (0.21; 1.79)	0.379

Note: COR: Crude odds ratio; AOR: Adjusted odds ratio; CI: Confidence interval *p-value ≤ 0.05 statistically significant

4.4 DISCUSSION

Our study is among the first to report data on oral health knowledge, attitudes, and oral hygiene practices of adult participants in Nyarugenge, Rwanda. The study revealed that among Nyarugenge adults, more than 40% exhibited knowledge deficits. The oral health attitudes and oral hygiene practices were also found to be poor.

The findings showed that 39.4% of the participants were young adults between 18 and 37 years old. A similar age group has been reported in India and Nigeria where the participants evaluated dental needs [24, 25]. The current results showed that most of the participants were women. Previous studies have reported a similar gender predominance citing that women were more proactive in seeking dental care [26]. Similar gender differences were reported in Saudi Arabia and India where it was found that women acted more positively than men on oral health [27, 28].

Our results showed that almost half of the participants had poor oral health knowledge. Our sample knowledge (58.0%) was lower compared to 62.2% reported in Nigeria, but it was similar to that reported in Spain with oral health knowledge of 58.5% [29, 30]. Although in our study participants knew that they must brush their teeth to prevent tooth decay (84.27%) and that to prevent gum inflammation, it is also necessary to clean between teeth (82.16%), most of them did not feel that a regular dental visit was necessary. Our study participants' knowledge of dental and gum care was lower than in the results reported in Cyprus at 97.3% and 96% respectively [31] and Romanians at 95.3 and 88.3% [32].

The knowledge of the participants in our study was strongly associated with the ownership of a smartphone ($P=0.011$), secondary education ($P=0.006$), good oral hygiene practises ($P=0.017$) and good oral health attitudes ($P=0.000$). A study conducted in Iran found an association between oral health knowledge and financial status, which can be reflected in our study as the ownership of a smartphone [33]. In addition, a similar association was reported between oral health knowledge and a higher level of education among adult populations in Spain [30]. More educated people are more likely to use reading, social media, news, and the internet to learn more. Bastani et al. found that smartphone-delivered oral health information enhanced knowledge [34]. The association between oral health knowledge and attitude was consistent with what was found in China [35] but contrasting results were found in the South Indian population [36]. These

differences might be due to different geographic locations, sociodemographic profiles of the participants and access to oral health care. The knowledge of study participants also reflected on their attitude, where 69.25% demonstrated a good attitude. This overall attitude was better compared to the South Indian, Saudi Arabian and Nigerian populations where the attitude levels were 33.3%, 48.3% and 44.5% respectively [36, 37]. The differences could be attributed to the different settings where the studies were conducted.

In our study, only 76.34% of the participants agreed that dentists should be visited regularly, even without having an oral problem. The participants agreed that waiting until they have a toothache before visiting the dentist can lead to tooth extraction. our findings are almost similar to the study with Libyan parents who agreed that regular dental check-ups are important for the prevention of dental problems at 79.5%[38]. However, the attitude of Romanian dental patients was better compared to our study participants because 88.3% of them agreed that regular dental check-ups can prevent dental problems[32].

Our study findings showed that the participants' attitudes were associated with oral health knowledge ($P=0.002$). A similar association between attitude and oral health knowledge was also found among Iranian patients [18] and Brazilian patients [39]. According to Rodrigues et al., a patient's attitude is a key construct for causing them to adopt a certain behaviour and maintain that behaviour[39]. The participants' attitudes in our study were also associated with ownership of a smartphone ($P=0.049$). The relationship between the ownership of the smartphone and the level of attitude could be that smartphone users tend to obtain more information online, which may improve their attitude.

The knowledge and oral health attitudes levels of our study participants did not translate to improve their oral hygiene practices. Only a third of our study participants displayed good oral hygiene practices in contrast to the Libyan study where 78.7% of parents displayed good oral hygiene practices[38]. Similarly, good practice findings have been reported in the literature [32, 33, 40] except in Brazil where low oral health literacy was associated with poor oral hygiene practises [33, 41]. Approximately 64.08% of our study participants brushed their teeth twice a day, compared to the Chinese dental patients who reported that 77.4% brushed their teeth twice a day [42]. Furthermore, 51.64% of our study participants responded that they should visit dentists only when they experience pain as compared to 55% of the Saudi Arabian participants[43]. The results of our

study found poorer oral hygiene practises in contrast to the Indian study where 82.0% of the participants went for routine dental check-ups and 25.8% expressed that the reason for their last dental visit was only consultation and advice[27, 38]. Dental flossing was not popular among our study participants because 92.7% reported never using dental floss. Similarly, dental flossing was low in Romania at 27.9% [32]. Oral hygiene practises in our study were found to be only associated with oral health knowledge. The result of our study differed from what was found in Brazil where level of education was associated with oral health practices[41].

One of our study's limitations is the use of a cross-sectional design, which cannot establish causality. However, we addressed this limitation by conducting a regression analysis that adjusted for confounding factors likely to influence the outcomes. Additionally, our study's sample bias arose from recruiting participants solely from government facilities, limiting the generalizability of results to those using private facilities. Moreover, because the data was collected from one district with a limited sample size, this study cannot be generalized to the entire country.

4.5 CONCLUSIONS

Almost half of the adults in Nyarugenge district had poor oral health knowledge, and one-third of them had poor oral hygiene practices despite showing good oral health attitudes. The discordance requires that oral health education and oral health attitudes be improved. The association between smartphone ownership and oral health knowledge was identified among the participants. This suggests an opportunity to utilize smartphones as educational tools for oral health alongside traditional methods to enhance knowledge and promote better oral hygiene attitudes and practices.

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CHAPTER 5

Evaluation of Oral Health Services and Challenges Faced by Oral Health Practitioners Working in Nyarugenge, Rwanda

5.1 BACKGROUND

In their daily work, oral health professionals (OHPs) fight common oral diseases, especially periodontal disease and dental caries, which are some of the most common non-communicable diseases and are even more prevalent than cardiovascular disease[1]. However, in this fight, either through prevention or treatment, OHPs encounter many challenges. The first challenge identified by researchers is financial because dental services are expensive and considered among the most expensive healthcare treatments[2]. Consequently, dental services are difficult to afford, especially in low-income countries and even in higher-income countries among people with lower income, senior populations, and marginalized communities such as refugees, migrants, and people with disabilities[3, 4]. In the USA, more people complain of financial barriers to accessing dental care, irrespective of age, income level, and insurance type, than any other healthcare. Most treatments are not always covered by national insurance schemes, and they cover only a small range of services[5, 6]. When confronted with the problem of financing, health professionals tend to focus on clinical procedures that provide them with better remuneration instead of on risk assessment or prevention, and many prefer working in private dental clinics where they can earn better salaries[7]. This suggests that public institutions are frequented by individuals who may be unable to afford costly dental treatments[8]. Singh et al. stated that most dentists target profit compared to patients' dental problems[9]. Therefore, some dental services are not offered in public institutions due to payment challenges and the expensive nature of some dental procedures.

The provision of oral health services is further compromised by lack of infrastructure, equipment, instruments, and materials. The lack of infrastructure at primary health centers and community health centers is a major hindrance to oral health delivery in India, and this may be due to the lack of dentists that are appointed in government decision-making bodies[9]. In care homes for the elderly in Germany dental professionals have requested that a dental chair with a light should be available in every care home to facilitate dental treatment[10]. The lack of OHPs has also been reported as a problem in South Africa[7]. The lack of infrastructure leads to few working stations

and few dental care providers, causing long patient waiting times, and the lack of equipment and materials impinges on the options and quality of treatments[11, 12]. In Nigeria, the lack of equipment and materials has been found to jeopardize the treatment options for patients and made OHPs to choose treatment procedures for which instruments and materials are available, such as tooth extraction[6]. The Rwanda National Strategic Plan for Oral Health 2019–2024 highlighted that in district hospitals and health centers, dental equipments, especially dental chairs, were either not available or not functioning due to lack of maintenance and lack of space for oral health services[13].

The biggest challenge experienced by OHPs when offering services has been linked to lack of human resources, which resulted to low dentist/patient ratios[14]. Different dental specialists are needed to collaborate in comprehensive oral examinations and treatment[15]. The problem of a shortage of dentists has been raised in the USA[16], and the situation is even worse in low- and middle-income countries. In Nigeria, the dentist/patient ratio was reported to be 1:38 600, whilst in Tanzania it was 1:360 000 but in high-income countries, it was 1:2 000[17]. Many health facilities in Nigeria have been found to have only one dental professional who does not have colleagues to consult about difficult cases [6]. OHPs' workload makes them overlook important steps in the diagnosis process, such as comprehensive oral examinations, comprehensive treatment care and oral health education. It is important to perform a comprehensive oral examination, including screening for early signs of all oral diseases, because it has been observed that most patients consult only for pain and dental emergencies[17, 18]. However, preventive measures are often neglected despite the goals of oral healthcare being a commitment to prevention[7, 9].

Apart from the financing of dental care, the availability of infrastructure and equipment, and the low dentist/patientratio, the behavior of many patients has also been a challenge. The lack of oral health awareness among the population concerning early signs and symptoms of oral diseases, preventive measures, and regular dental check-ups resulted in late dental care-seeking behavior[6]. Even when patients have an infected tooth that can be conserved, it is challenging to convince them to comply with alternative treatments such as root canal treatments because they visit the dentist only when the pain is unbearable and insist that the tooth be removed[6, 19]. All these challenges are mostly due to oral healthcare not being included in the primary healthcare system. Oral healthcare should be integrated into primary healthcare to make it available to all people [6]. The adoption of healthy oral health preventive measures cannot take place if patients and

caregivers are not given oral health education by OHPs on good oral hygiene practices such as frequent brushing, good brushing technique, interdental cleaning, regular dental check-ups, diet, and smoking cessation for the prevention of both periodontal diseases and dental caries[16].

The above-mentioned challenges can be addressed through good management. Some managerial barriers to good and equitable oral health identified in the literature are unclear goals, inadequate organization and management, poor planning, little emphasis on evaluation, and failure to plan for adequate manpower and use of auxiliaries[9]. It has been observed that dental service is often neglected during recruitment and procurement processes[6, 8, 13]. Literature demonstrates that there is international neglect and a lack of political prioritizing of oral health[16, 20]. Many public policymakers do not understand or value oral health as part of general health, making it a lower priority[9]. The affordability of dental services, the skills of OHPs, and the availability of dental equipment and materials all play important roles in the provision of comprehensive oral care, and this is the responsibility of the management of health facilities[17].

This study explored the challenges faced by OHPs in providing oral health services to the community of Nyarugenge, Rwanda. In addition, the availability and adequacy of oral hygiene equipment, instruments, and materials were also appraised. This study formed part of a larger doctoral study titled “Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Applications in Oral Health Education”.

5.2 METHODS

5.2.1 Study design

This study was a cross-sectional concurrent mixed methods study that used both qualitative and quantitative methods. The qualitative part of the study aimed to explore the challenges faced by OHPs when providing oral health services to the community of Nyarugenge District, and the quantitative part was an audit of oral health services in Nyarugenge District. The quantitative and qualitative parts were independent during data collection and analyses but were merged during the interpretation phase.

5.2.2 Setting

Rwanda is one of 56 countries in Africa. Rwanda is divided into four provinces and Kigali City. The four provinces each have 27 districts, and Kigali City has three districts, namely Gasabo, Kicukiro, and Nyarugenge[21, 22]. The study was conducted in seven public health facilities that

offer dental services in Nyarugenge District. Five health facilities are public and two are managed conjointly by the government and the Roman Catholic Church. These health facilities service all patients, including those using community-based health insurance (CBHI).

5.2.3 Study population and sampling strategy

The quantitative section of the study assessed the seven public dental health facilities in Nyarugenge District, and for the qualitative section, OHPs working in the seven dental health facilities were individually interviewed. No sampling was done. All seven dental health facilities in Nyarugenge District (n = 7) and all OHPs working in these facilities were included in the study. Fourteen OHPs were recruited for in-depth interviews.

5.2.4 Data collection

The data collection tools for both the quantitative (observation checklist) and qualitative data collection (interview guide) were adapted from a study conducted in 2018 by Josephin et al.[23]. The data collection was started on 18 July 2022 and ended on 01 August 2022. The checklist items for the quantitative data collection assessed the availability, adequacy, and functionality of dental equipment. The in-depth interview guide had 12 questions related to various scenarios experienced by OHPs when providing oral health services to the community. The 12 questions asked during the in-depth interview were as follows: (1)How is your work now? (2)What suggestions can you make so that your work becomes much easier? (3)Do you manage to give oral health education to every patient that comes to you? (4)Are you able to provide scaling and polishing treatment to all the patients who need treatment? (5)Do you get time to sterilize and reuse instruments for scaling and polishing according to need? (6)Do you get time to give oral hygiene instructions to patients after a procedure? (7)Are you satisfied with the quality of treatment that you are offering to your patients? (8)What happens when one of the equipment in the dental clinic stops working or needs repair? (9)When dental materials like polishing paste finish, is it replaced immediately? (10)Do you feel that you are at risk while providing treatment? (11)In your opinion, what would decrease your workload? (12)What are your suggestions to improve oral hygiene treatment facilities in the dental clinic?

Following informed consent, the primary investigator (EN) conducted the interviews with the OHPs in a private room. The in-depth interviews were conducted in English and interpreted in Kinyarwanda, the local language, when necessary. Each interview lasted around 30 minutes. The

responses of participants were audio recorded, transcribed verbatim, and saved as individual Microsoft Word documents soon after the interview. At the end of the interview, an audit of the dental equipment was performed using the observation checklist.

5.2.5 Data analysis

Descriptive statistics were used to analyze the quantitative data using percentages and frequency distribution. The dichotomous responses, 1 equals *yes* and 0 equals *no*, to identify the availability, adequacy, and functionality of the dental equipment, instruments, or material needed for scaling and polishing were recorded. Data were entered manually on an Excel spreadsheet and then imported into Stata version 16 (manufactured by StataCorp LLC in USA) for analysis. For the qualitative data, the recorded interviews were transcribed and imported into NVIVO software (manufactured by QSR International) for a detailed analysis.

The interviews were analyzed using thematic content analysis[24]. The first step in the analysis was to look at the participants' own words and phrases without preconceived notions or classifications. We examined in deep the responses of each participant's answer to all the questions.

To ensure trustworthiness, two additional researchers, an experienced qualitative researcher in health systems and a dental specialist, participated in the development of the codes by reading the participants' responses independently from the primary researcher to establish an inter-coder agreement. Once the initial analysis was completed, the team liaised to discuss the codes generated independently and to reach an agreement on the codes and themes.

5.2.6 Ethical statement

The research received ethical approval (M220213) from the University of the Witwatersrand Human Research Ethics Committee (Medical). Additionally, permission was obtained from the relevant healthcare authorities, including the Rwanda Institutional Review Board (IRB) ethical committee (No. 234/CMHS IRB/2022) and the National Health Research Committee (No. NHRC/2022/PROT/26). The written informed consent form was obtained from the participants.

5.3 RESULTS

5.3.1 Description of the study sample

Seven facilities were audited for the availability, adequacy, and functionality of equipment for preventative dental services. Furthermore, 14 OHP from these facilities were interviewed about the challenges they face when providing oral health services to the community.

5.3.2 Frequency distribution of health facilities with essential dental equipment and instruments

Table 5.1 shows that five health facilities had dental chairs but only four of these chairs were fully functional. Only two health facilities had adequate dental chairs, dental lights, and dental stools. All health facilities had functional and adequate sterilizing units. The manual scalers were available and functional in all seven health facilities, and five facilities had available and functional equipment and instruments for scaling and polishing. However, the adequacy was low concerning the ultrasonic unit ($n = 3$) and ultrasonic scaler tips were inadequate. Functional prophylaxis handpieces, prophylaxis contra-angle, and prophylaxis cups/brushes were found in four of the facilities. Polishing material was also inadequate in three facilities.

Table 5. 1 Preventive dental equipment, instruments and material audit availability

Equipment/instruments	Availability		Functionality		Adequacy	
	Yes	No	Yes	No	Yes	No
Dental chair	5	2	4	3	2	5
Dental light	5	2	4	3	2	5
Dental stool	5	2	5	2	2	5
Dental compressor	5	2	5	2	5	2
Suction lines	6	1	5	2	5	2
Sterilizing unit	7	0	7	0	7	0
Ultrasonic scaler unit	6	1	5	2	3	4
Ultrasonic tips	6	1	5	2	0	7
Manual scaling set	7	0	7	0	4	3
Suction tips	5	2	5	2	4	3
Instruments for polishing	5	2	5	2	4	3
Prophylaxis handpiece	5	2	5	2	4	3
Prophylaxis angle	5	2	5	2	4	3
Prophylaxis cup/brush	5	2	5	2	4	3

5.3.3 Frequency distribution of health facilities with essential dental material

The materials for oral hygiene instructions, oral examination instruments and personal protective equipment (PPE) availability and adequacy from the facilities were analysed. Only two health facilities out of seven had a demonstration model, toothbrush, and dental floss for interdental cleaning during oral hygiene instruction. None of the health facilities used a mobile application for oral health education. All seven health facilities had dental probes, mouth mirrors, and dental trays, but only six had periodontal probes. However, all these instruments were adequate in only four health facilities. Six of the health facilities had all personal protective equipment and they were adequate. The mouth masks were available and adequate in all the health facilities.

5.3.4 Demographic characteristics of OHPs

Overall, the total number of OHPs was 14, with five based in health centers, three in district hospitals, and six in referral hospitals. Most respondents were dental therapists (n = 11), and the dental surgeon (n=3). The females (n = 9) were predominant, and the majority of the participants were aged between 31 - 40 years (n = 7). The 41–50 age group included 4 OHPs, and in the 21–30 age group had 3 OHPs. The years of practice of the OHPs revealed that (n=6) OHPs had more than 10 years, 6–10 and 1–5 years of experience had 4 OHPs respectively. |

5.3.5 Emerged themes

Although overlapping, four broad themes emerged from the responses of OHPs in the in-depth interviews, shown in Table 5.2, and these themes are discussed in the following subsections.

Table 5. 2 Themes that emerged from OHPs’ experiences in Nyarugenge District

Themes	Description
1. Human resource	• Poor OHP/patient ratios • Lack of dental assistants
2. Supply chain management	• Insufficient of equipment • Insufficient instruments, • Insufficient dental materials
3. Patient education and service rendering	• Lack of public awareness • Delayed oral healthcare seeking practices • OHP workloads
4. Strategic management and administration	• Health system responsiveness • OHPs’ attitudes and behavior (pleasant, rude, or caring attitude) • Management of service provision; inadequate or lack of communication

5.3.6 Human resources

Apart from the OHPs working at the district hospital who reported that the patient/practitioner ratio was manageable, all the other OHPs complained about patient overload. In five of the health centers, there was only one dental therapist managing all the patients. The understaffing resulted in complaint-oriented service instead of comprehensive holistic dental management. Furthermore, the OHPs had to rush to clear the long queues and cannot not perform other treatments such as scaling and polishing or dental fillings since many patients have acute pain. In addition, ensuring good infection control can be challenging when the practitioners are working alone without a dental assistant. The following comments by the OHPs gave a clearer picture of the situation:

“The number of patients is higher compared to the number of dental practitioners. Sometimes you have to rush in order to clear the line of patients.” (Participant 2)

“When there are many, we sometimes don’t do a deep intraoral examination and concentrate only on the chief complaint instead of doing a comprehensive oral exam.” (Participant 5)

“Sometimes I am not happy due to the large number of patients. So I cannot satisfy all their needs. We can skip doing some treatments like scaling and dental fillings due to that number.” (Participant 12)

“You understand that this is a big challenge. If we have to work as four hands and you are there alone, helping yourself, it is not correct.” (Participant 11)

Another challenge expressed by the OHPs working at the district hospital and the referral hospital was the lack of specialists. The waiting list and time are long for patients who must be seen by a specialist, and it was reported that some patients with oral cancer have died while waiting for treatment. Furthermore, since there is no dental surgeon at the district hospital, even patients requiring simple endodontic treatments and impacted teeth removal are referred to the hospital. Unfortunately, when patients arrive at the referral hospital, they can be turned back because of lack of dental material, and then they must get another referral to the Rwanda Military Hospital. That was distressing for both the patients and the practitioners, as shown in the following comments:

“Bring also dental surgeons so that more services would be offered from here. Patients would receive a bigger package of dental care forms here; references would be reduced.” (Participant 3)

“I think they should train more specialists. Currently, we have only one maxillofacial surgeon dealing with accidents and emergencies. You find that a patient with orofacial cancer can die without even being examined by the specialist.” (Participant 7)

It is imperative to recruit more OHPs for primary oral healthcare services because if this is not done, the quality of care offered in public health facilities will continue to be compromised.

5.3.7 Supply chain management

The OHPs reported that they do not have sufficient equipment, instruments, or materials to offer dental care to the community. The audit findings from the checklists showed that two health centers did not have a dental chair, and of the five health centers that did have a dental chair, only four had a fully functional one. At the referral hospital, only two chairs out of four were available and could be used for ultrasonic scaling. The situation was similar at the district hospital, where only one chair out of two was available, fully functional, and could be used for ultrasonic scaling. Three health centers had one dental chair each, but only two of these chairs could be used to perform ultrasonic scaling. In general, no dental clinic had adequate equipment for the number of patients. As shown in the following comments, the OHPs expressed that the lack of equipment, instruments, and materials impacts the oral healthcare they provide to the community:

“Concerning equipment, since we have many patients who need our services, it would be much better if we had more equipment. Currently, we have only one dental chair. It would be better if we had two of them. More equipment should be purchased to serve the population better.” (Participant 8)

“Most of the time we don’t have enough materials for all the patients. Some patients get good service while the others get lower service because some materials have finished.” (Participant 9)

Competing priorities in hospital settings between dental services and other services, such as maternity or pediatric services, were cited by OHPs as reasons for the lack of dental resources. The dental equipment could be damaged and not be repaired, and consumables were finished and

not procured, resulting in patients waiting a long time before receiving treatment. This is a challenge at almost all the surveyed health facilities. Usually, in public health facilities, tender and procurement processes take a long time, which means that some items that are received are used immediately because the waiting time was so long. The following comments by participants express this challenge:

“That is also a challenge. It doesn’t mean that the materials are nowhere to be found, only that the process is long ... sometimes you get them too late when it is no longer possible to help the patients. You can make a request today and wait a whole year for delivery.” (Participant 9)

“The priority is given to the maternity, pediatric, and neonatology services. The dental service lags in the process of supplying.... we always wonder if the dental service is futile or is not generating money so that its revenues cannot help to buy a scaler. If a scaler has been functioning for like two years, it is not understandable that the money generated during that period cannot buy another one to replace the damaged one. That is always a challenge.” (Participant 1)

Even though six of the seven dental clinics had ultrasonic scaler units, most of them did not have enough scaler tips, which led to overuse until the tips were no longer efficient. In many of the facilities, they can book only two patients per day, despite the need to book more patients. The availability and functionality of the scaling instruments were optimal, but when compared to the number of patients who needed this treatment, it was inadequate. The problem is worsened by the fact that dental clinics are no longer allowed to have a sterilizer on the premises, which would have allowed them to sterilize scaling instruments between patients. The new protocol means sterilization can only be done at the main sterilization unit of the hospital or the health center. These new protocols result in delays in the sterilization process and the availability of sterile instruments, negatively impacting services. The OHPs described the problem as follows:

“These types of equipment and materials should be in enough because many patients are having a lot of calculus. Sometimes even when they have another chief complaint, you might wish first to clean their teeth before proceeding with the filling or the extraction in order to work in a safe oral environment.” (Participant 3)

“I had requested 30 scaler tips, but I have only two. But even those two are no longer functioning perfectly because they are overused.” (Participant 11)

“I become stressed because I see patients who need (preventive) services. Telling someone to come back after one month is very frustrating. You would like to serve them immediately but due to the shortage of equipment, you are obliged to give a rendezvous one month later.” (Participant 11)

“We sterilize in a big container from the autoclave at the theatre and in the morning, they bring them back and put them in small boxes.” (Participant 5)

After scaling, it is necessary to polish dental surfaces to prevent a rapid re-accumulation of calculus. However, only three sites had the necessary polishing paste, and most of it was of poor quality and could not perform good polishing. The service of polishing teeth posed another challenge because it is not covered by the CBHI scheme, which is mostly used in public health facilities. Therefore, many patients attending public health facilities cannot afford to pay for teeth polishing services. The result is unpolished dental surfaces that attract dental plaque and calculus more quickly, which discourages patients and makes them believe scaling is more harmful than beneficial to their oral health. The following comments by the participants explain this problem:

“We would also like to get the polishing paste whenever we need to use it. People start to be aware and to look for better oral hygiene.” (Participant 3)

“The request of consumables is done on time, but since we are in a public hospital, the process of delivery is very long so at given times we stop doing some procedures because dental materials are not there. That process causes us to experience stock-outs.” (Participant 2)

“The only consumables they care to avail are those linked to tooth extraction. But for the others, the administration is reluctant.” (Participant 12)

The adequacy of diagnostic dental instruments was low in all seven health facilities considering the number of patients received daily, except for personal protective equipment. The COVID-19 pandemic improved the availability and adequacy of personal protective equipment in all health facilities because administrators of health facilities realized the importance of personal protective equipment in protecting patients, practitioners, and colleagues.

5.3.8 Patient education and service rendering

The heavy workload of OHPs leads to them overlooking important practices such as oral health education. The OHPs said that it is almost impossible to give oral health education to every patient they examine. The OHPs give superficial oral health education to patients with halitosis or poor oral health status, but only OHPs working in two health facilities said they found time for thorough one-on-one oral health education. This is possible because another dental therapist was recently recruited at one health center, which means the district hospital staff are no longer overloaded. This resulted in improved OHP/patient ratios. This proves that the will to do oral health education is there but that the practitioner/patient ratio makes it impossible. However, the OHPs confirmed they give postoperative instructions to every patient after treatment regardless of their overload. The following comments by the OHPs show the extent of the problem:

“It is not possible to give oral health education to every patient. Most of the time, we do it for patients with poor oral health status or with halitosis. That is when we tell them that they have to brush their teeth.” (Participant 5)

“We only tell them to remember to brush their teeth in the morning and at night before going to bed. Only that.” (Participant 7)

“Giving oral health education to every patient is challenging because patients are many. You only tell them about the act itself you are about to do for them or, after completing the procedure, giving them related instructions. Otherwise, it is very challenging unless you do mass education, but they don’t come at the same time.” (Participant 4)

“There are also some people who don’t want to hear what you are telling them, thinking that you are wasting their time while you wanted them to acquire some awareness.” (Participant 3)

Patients are unaware that it is better to prevent oral diseases than to cure them and that teeth can be cleaned professionally. They often realize that there are some deposits on their teeth and try to remove them with charcoal, which causes more dental problems like enamel abrasion. Most of the patients seek dental services because of pain. Even when OHPs see the need for scaling and polishing and gave them an appointment, the patients do not come for the treatment. According to the OHPs, most patients do not listen to the advice they are given during individual or mass oral

health education and consider it a waste of their time. One OHP said that the reason for this is that there are no OHPs recruited in the community to teach them oral hygiene measures and to screen their mouths for early detection of diseases. Community oral health prevention should be established and consolidated because it will tackle the problem of oral health at the root, especially since individual dental self-care by tooth brushing, including interdental cleaning, is the most important preventive measure for periodontal disease and dental caries. Furthermore, patients should cooperate with OHPs and quit harmful habits such as smoking, alcohol, and drug abuse.

“There should be dental personnel affiliated in the community to educate people about oral health. That would be very good”. (Participant 4)

Oral health education is also a challenge because of a lack of teaching aids and promotional material. Only one health center, managed by sisters of the Roman Catholic Church, had all the necessary didactic materials for oral health education. The facility had a big teaching model and a big brush they could use to clearly show all the parts of the oral cavity and how to clean them. Participant 8, who works at this center, said, “First of all, we have didactic materials in our office. We have a big toothbrush and a big model that we use to show them the technique for tooth brushing. We also show them the gum and the tongue on the model. You see that this model is showing all the parts of the mouth”. The only other health facility with a small dental model teaching aide is the district hospital. At all the other centers, oral hygiene measures are taught using gestures, and it is impossible to verify whether patients understand what they are taught. The OHPs did not even have dental floss to show patients how to clean interdental spaces and had to teach patients only in theory. The lack of time due to patient overload and the lack of didactic materials negatively affect oral health education, which is the basis for oral disease prevention. Participant 5 explained it as follows:

“We don’t have typodonts and materials which would help us to explain the technique for dental brushing. When we do it only in theory, we are not sure of the outcome. Didactic materials should be available on our consultation tables, but we don’t have them ... we only give oral health education in theory, but we cannot verify if they understood well or not.” (Participant 10)

The large number of patients seeking dental care reflect the oral health status of the community. The poor oral health status of the community could be improved if oral health education is

improved through measures such as active, practical education through people's mobile phones. All the interviewed OHPs were amazed by such an idea and recognized that the application would make their job much easier because patients would come to them with some knowledge about oral health and ask questions to clarify the information they received on their phones. If the information is updated regularly with clear audio-visual materials, it will positively impact people's oral health, even in remote areas. The following comments show the OHPs reactions to the idea of a dental mobile application:

“People would be aware of when and how to perform oral hygiene and consequences of poor oral hygiene.” (Participant 14)

“That is where that application would play a role in raising the awareness of our clients about oral health. The communication between dental patients and dental practitioners would be smoother. That wouldn't take us a lot of time trying to convince them about the best treatment.” (Participant 1)

“That is why the application you were telling me about would be very useful because problems start at the community level, not at the health facility ... since oral problems can be prevented, and the application can help them in that, it would be good if it was installed in people's phones and was used. It would remind them how to clean the mouth.” (Participant 4)

An oral health education mobile application would promote community oral health awareness, help children, youth, adults, and even old people maintain their oral health and show them early signs of disease so they seek dental care in time. It would inform the population of the importance of regular dental check-ups instead of waiting to get dental care only when in pain. It would also improve people's oral health literacy, which would ease their communication with OHPs and increase their compliance with preventive measures.

5.3.9 Strategic management and administration

Many of the challenges faced by the OHPs could be addressed by management. Management plays a crucial role in staff recruitment, motivation and the procurement of proper dental equipment and materials. Management's role is also related to reducing patients' waiting time by increasing the number of working stations by supplying dental chairs and employing dental assistants. A good

workplace should be a safe environment for both patients and practitioners, and OHPs should feel valued by the administration.

“It is challenging to serve such a big number of patients while we don’t have enough working stations so that each one might work from his/her dental chair”. (Participant 9)

Poor strategic management and administration were particularly observed at two health centers where OHPs lacked basic equipment such as dental chairs and basic instruments despite constant requests. At one health center, dental extractions and manual dental scaling are performed using archaic equipment. The OHP working there reported that requests sent to the Ministry of Health can take long and that they often receive no response.

“Here, we don’t have dental equipment. We have asked for them, but we haven’t yet received them I would be happy if they bought for me new and modern equipment”. (Participant 6)

At another health center, the dental chair had been taken during the COVID-19 pandemic and given to another health center in a different district because the health center had become an isolation center for COVID-19 patients. The participant explained that they have asked the administration to return the equipment but to no avail:

“If the dental chair and all needed instruments, equipment, and materials were available so that when the patient comes and needs any treatment they might get it, this would satisfy me”. (Participant 10)

The OHPs are frustrated because their requests for dental instruments and materials are ignored by management. The OHPs believe that the lack of dental representatives in the procurement committees is the reason their orders are not approved. Procurement and supply chain committees/personnel are unfamiliar with dental jargon, instruments, consumables, and requirements and do not consult the OHPs when they require information. The OHPs explained the problem as follows:

“They don’t supply us with dental materials on time so that we might serve our patients in a good and satisfying way.” (Participant 3)

“Another thing, even when they provide, usually they bring a different item from the one you requested. As a recent example, we requested drilling burs and they brought polishing burs, while we needed inverted cone bars.” (Participant 2)

Only health facilities managed conjointly with the Roman Catholic Church seem to prioritize dental services and procure what was needed, as shown by the following comments:

“There is no problem here even for equipment. I can say that our administration is valuing dental service even more than I do.” (Participant 8)

“Concerning sterilization of instruments, we never lack instruments here. We are privileged because this health center belongs to the Catholic Church so basic instruments are there. Even though they cannot be enough for all the patients, we clean and sterilize them. Our instruments are safe because we have a sterilizer in which instruments are ready in 45 minutes. We don’t have any problem with that.” (Participant 8)

All dental equipment, instruments, and materials, including those for preventive services, must be made a priority in managers’ demand and operational plans. It was found that when the administration is supportive, the working environment is improved and OHP satisfaction is high. This was confirmed by the staff at the referral hospital who reported that they benefit from a supportive working environment. Their equipment was well-maintained and more staff were being recruited to assist in the X-rays section. When dental equipment remains unrepaired for a long period, it shows that the dental services, OHPs, and patients are not valued.

“Our department has an appointed technician, a medical engineer charged with repairing dental equipment. He is based in the department of maintenance, but when we call him, he immediately comes. He is skilled. Not many things are difficult for him.” Participant 13

During the interviews, the OHPs were asked what would ease their work. Firstly, they said they would like the patient/practitioner ratio to be reduced by recruiting more dental staff and by increasing work stations. This will allow them to work the recommended hours instead of working extra time. Secondly, they would like to have the necessary equipment and materials, a better salary, and tea or coffee breaks at work because even though they like their job, it is hard work. Thirdly, although the organogram of the health centers plans for only one dental therapist, they

want it to be revised so that at least two OHPs are hired per facility because the primary healthcare facilities are extremely busy.

5.4 DISCUSSION

This study evaluated oral health services and the challenges faced by OHPs when providing oral healthcare in Rwanda. The study found that there were variations across the seven healthcare centers in terms of human resources, supply chain management, patients education and service rendering, as well as strategic management and administration.

When considering the results of the checklists and the interviews used in the current study, it appears that one of the biggest challenges faced by OHPs while delivering preventive oral health services was linked to human resources. There was a shortage of personnel, such as dentists, specialists and dental assistants. This impinges on oral health service delivery, which is a factor in patient and practitioner satisfaction. This concern has also been raised by researchers in Nigeria and India, where it was found that there is a limited number of dentists compared to the number of people who need dental care[6, 25, 26]. The challenge of understaffing has also been identified in many other low- and middle-income countries, and this limits access to oral healthcare[17].

In addition, most OHPs were dental therapists, and there is a scarcity of dentists and specialist OHPs. The situation is different in South Africa where oral health services are provided by oral hygienists, dental therapists, dentists, and various dental specialists[7]. It was also different from what was reported by a study performed in 47 WHO African countries that found that there are more dentists than dental assistants and dental therapists[5].

Another challenge highlighted in the present study was linked to supply chain management, where it was found that there was a lack of adequate dental equipment, instruments and materials, which was impacting the delivery of preventive dental care[27]. A study performed in Fiji identified the same challenge where OHPs complained of a lack of proper equipment and materials because the available materials were often of poor quality, and this prevented them from performing good-quality work. OHPs in Fiji revealed that they could not offer all services within their scope of practice because they did not have the necessary resources[28]. Similarly, in India, public facilities have been reported to be poorly maintained or to have outdated dental equipment[25]. In the current study, many of the health facilities did not have polishing paste, supposedly because it is not covered by CBHI and patients cannot pay for it themselves. Apart from the polishing paste,

periodontal probes were also absent in one health facility and prophylactic prophylaxis angles and prophylaxis cups or brushes were inadequate in general.

However, the results of the current study differ from the results of a study conducted in Tanzania, where only a quarter of facilities had fully functional dental units. OHPs felt that their profession was being neglected[17]. This feeling of being undervalued was shared by the participants in the current study, where most of the OHPs felt that dental services were not valued, and therefore, there were often lags in the procurement process, particularly for preventive equipment and materials. Similar results were reported in Nigeria, where it was found that in the allocation of health resources, decision-makers pay little or no attention to oral health prevention programs because oral healthcare is seen as insignificant compared to other health areas[6]. Similarly, in India, it was found that when primary healthcare systems are implemented, dental health is not included, leaving dental healthcare far behind other health services in the procurement process[25].

Patients' education and service rendering was another challenge identified in the present study. In fact, participants revealed that it was very challenging and quasi-impossible to provide a full package of oral health education to every patient. They only managed to give postoperative instructions and do some chairside oral health education, especially related to the treatment rendered. Needleman et al. highlights that postoperative oral hygiene instructions may be more important than mechanical plaque removal itself[23, 29]. However, oral health education is vital and it should be comprehensive. Its importance was demonstrated in Honduras, where it was proven that education can help prevent oral diseases because it is key to behavioral change[30]. Communities should be encouraged to adopt healthier lifestyles to live longer and healthier lives[31].

The patient's lack of knowledge and awareness about oral health results in seeking dental care only when they are in pain, and at that time, more invasive and expensive care is necessary. This leads to periodontal problems often being discovered at a late stage when the teeth have already become mobile. In fact, patients worry about their oral health when it becomes painful, and they often visit OHPs with complications from dental caries[26]. The literature shows that early check-ups and regular preventive care reduce the need for dental operative services[32, 33]. Therefore, in the present study, when asked about the mobile dental application, the participants were eager to see a mobile application installed on patients' mobile phones to continuously offer updated oral health

information to people, even in rural and remote areas from which most patients come. In fact, it is believed that mobile phones offer a promising strategy for dentists to reach the public and deliver low-cost oral health education and promotion. A mobile application for oral health education has been proven to be effective in teaching patients how to take care of their oral health at their convenience time and place[34]. The application can be used to teach the population how to maintain good oral health, proper diet and nutrition, and the importance of routine dental check-ups[35]. If people know how to prevent oral diseases, there will be less dental patients, and patient/practitioner ratios will improve[33]. The importance of oral health promotion and education has been also highlighted in other studies. Interventional studies performed in different countries demonstrated that the attitude of parents who were taught about the oral health of their children in the intervention group improved and contributed to a significant increase in the oral health status and oral hygiene of their children, while in the control group, children had more dental caries on their deciduous molars [36-38]. This confirms that strong oral health promotion and education is the basis for oral health solutions.

In the present study, the findings showed that another challenge faced by OHPs is linked to strategic management and administration. In fact, it is the responsibility of health facility administration to ensure the recruitment of enough staff and the procurement of dental equipment, instruments and materials. However, even the few dental personnel who are available feel demotivated. Even though OHPs reported that they love their profession, they could not deny that it is tiresome, and therefore, they would appreciate and be more motivated if they received financial bonuses and incentives such as tea breaks during work hours. Suga et al. found that dentists are willing to provide dental caries preventive measures if their payment schemes were fairer[33]. The management of public health facilities should review their planning system so that dental services are equipped with essential equipment, basic dental materials and instruments, and proper human resources.

The management should also advocate for patients in insurance companies or provide standard required treatment regardless of the insurance cover. In this study, it was discovered that the fact that dental polishing is not covered by CBHI discourages dental practitioners from providing dental polishing treatment, which hasten the dental plaque accumulation on scaled dental surfaces. The impact of medical insurance on dental service accessibility has also been raised by Ramraj et al. and Uguru et al. because they found that not only low-income groups but also middle-income

groups struggle to access comprehensive dental care because some acts are not covered by medical insurance[6, 39]. Therefore, it is not enough to have health insurance, and the insurance should also cover at least all basic dental services, such as dental polishing[40, 41]. The problem of health insurance covering only a few dental procedures was also found in Nigeria, where some treatments are not provided due to lack of insurance coverage[6]. The CBHI should be encouraged to cover polishing because it is not very expensive. Basic oral healthcare coverage, including prevention, is patients' right. Efforts must be made by the management to support and advocate for preventive oral health service coverage, such as polishing, through the CBHI. This is highlighted by Bastani et al., who emphasized that policymakers in low- and middle-income countries should aim to improve populations' access to oral and dental services through advocacy for comprehensive insurance packages because millions of people in developing countries cannot afford basic dental treatments [42]. Hayashi et al. said that dentistry should move from an increasingly unaffordable curative model to a cost-effective evidence-based preventive model[31].

5.5 LIMITATIONS

The limitations of this study were that participants were recruited from a single district and only from government institutions, which means the results cannot be generalized to the entire country or private facilities. The quantitative data that was measured using an observation checklist was not all-inclusive, and some of the equipment/consumables required (e.g: Restorative materials, airtors) were not included in the audit. The study checklist focused on preventive oral hygiene services and required materials and equipment used for scaling and polishing.

5.6 CONCLUSIONS

The challenges faced by OHPs in Nyarugenge District were related to the following areas: human resources, supply chain management, patients' oral health awareness and service rendering, and strategic management and administration. However, if one looks closely, it appears that all these challenges can be addressed by proper management of the health facilities. Proper and optimal strategic management of public health facilities would make an effort to recruit enough personnel which would free time for OHPs to provide oral health education and other preventive measures and to do comprehensive oral examinations, which would allow early detection and, thus prevention, of oral diseases[43]. Furthermore, the management of health facilities should ensure the availability of dental equipment, instruments and materials for oral disease prevention and remember to prioritize community oral health promotion and education in order to raise the

awareness of the population towards oral health. Well-established community preventive interventions such as a dental mobile application would help improve patient/provider ratios because it would raise awareness about oral health and help people adopt healthy behaviors. Finally, the management of health facilities should also make advocacy for the population so that more dental services would be covered by health insurance, especially the CBHI, which would allow OHPs to offer oral health services without constraints.

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CHAPTER 6

The Feasibility and Acceptability of a Mobile App for Oral Health Education Among Adults in Rwanda

6.1 BACKGROUND

Oral health is an essential part of overall well-being. However, many adults lack adequate knowledge and practice for good oral hygiene. Patients have traditionally accessed advice about their oral health from the dental team, but this has limitations such as inequalities and disparities in oral health services, especially to remote and underservice populations as well as lack of affordability to dental care. Mobile health applications that utilise mobile phones and other wireless technologies offer a promising alternative for delivering oral health education in a convenient, accessible, and engaging manner.[1] Mobile Apps have been shown to support education, business enterprise and service delivery. In health using information technology, consultations and self-care can be performed, to promote patients' autonomy and independence.[2]

Mobile Apps for oral health education have been found to promote regular tooth brushing, thus decreasing plaque and gingival index[3] as well as improving and enhancing oral hygiene.[4] Mobile phones are among the tools through which messages can be cascaded, including other electronic media such as emails as well as printed documents; news apers and pamphlets. Patients and healthcare providers can now stay in touch from any location to continue their follow-up, ask questions, collect information, inquire about or provide test results, schedule appointments, send reminders, and renew prescriptions.[5] However, certain demographic factors, such as older age, living alone, having less education, earning a lower salary, and residing in a rural area were found to be linked to low utilisation of eHealth services.[6]

The BrushDJ oral health App is designed to motivate users to brush their teeth effectively to be used for both children and adults. The App provides basic oral health education through videos, text, and pictures tailored for various age groups. Its primary focus is to enhance users' oral hygiene by demonstrating appropriate techniques.[7] The BrushDJ oral health App has been reported to

motivate the participants to brush.[8] In a study conducted in Brazil, people who received oral health education from a mobile oral health App have reported to retain the acquired knowledge better than those who received verbal health guidance alone.[9] Mobile oral health Apps can offer oral health education in a fun way, which attracts children and youngsters. While playing, they can learn useful methods to promote their oral health.[10] Therefore, all levels of the population can benefit from oral health education through smartphones, even in remote rural areas, provided there is internet coverage and availability of data to access the mobile App. Parents and caregivers can access information on how to maintain good oral hygiene for their children, thus helping to reduce early childhood caries.[11] Mobile Apps for oral health education have been developed elsewhere, and some studies have shown that they can effectively improve oral health knowledge and practices.[12]Based on the literature findings above, mobile technology has the potential to help the community to maintain their oral health. However, there is scarcity of information regarding mobile oral health App usage in Africa for oral health promotion.

The Government of Rwanda has started to invest more in information communication technology (ICT) to speed up the delivery of online health services.[13] Mobile phone penetration in Rwanda is high, with over 80% of the population owning a mobile phone.[14] Mobile health interventions have been successfully implemented in Rwanda for other health issues, such as maternal and child health.[15, 16] Rwanda has adopted online health consultations, allowing patients to receive expert advice from health professionals through phone calls. In addition, Rwanda has started a project called Connect Rwanda, which focuses on bringing one smartphone per family; many citizens have received their smartphones to access online services easily.[17] Despite these encouraging strides, there are still gaps in the delivery of online oral health education and information to the communities. The widespread use of smartphones presents an opportune moment to improve oral health education and promotion interventions.

The aim of the study is to assess the acceptability and feasibility of using the mobile oral health Apps, BrushDJ, to enhance patients' oral self-care at home in Nyarugenge District of Rwanda. The study will contribute new knowledge on the feasibility and acceptability of a mobile oral health App designed to improve oral health. The null hypothesis (H_0) is that the mobile application was not acceptable and feasible to use for oral health education. The alternate (H_A) is that the mobile application was feasible and acceptable for oral health education. This study formed part of a larger

doctoral study titled "Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Applications in Oral Health Education".

6.2 METHODS

6.2.1 Study design

This study involved a cross-sectional survey designed to evaluate feasibility and acceptability of mobile App for oral health education. This was done through a survey directed to individuals attending public health facilities in Nyarugenge District, Rwanda.

6.2.2 Setting

Rwanda is one of Africa's 56 countries. It is divided into four provinces and Kigali City, which serves as the capital. The four provinces are subdivided into 27 districts, while Kigali City itself comprises three districts: Gasabo, Kicukiro, and Nyarugenge, according to government data.[18, 19] The study took place in July 2022 in the Nyarugenge District of Kigali City, Rwanda.

6.2.3 Study population and sampling strategy

The study participants were recruited from adult patients who are 18 years old and above who met inclusion criteria such as owning a smartphone and being able to understand English or French. These participants have been recruited in our previous study which assessed oral health knowledge, attitudes, and practices (KAP) across three health centres in Rwanda. The KAP study recruited 426 participants, and the sample included only individuals who were 18 years old or older and lived in Nyarugenge District, Rwanda.[20] During sampling for the current study, some participants out of 426 were excluded (n=315) because either they did not own a smartphone, they did not sign the informed consent, or they were not able to understand English or French. Eventually, 111 participants constituted the total sample size of the current study.

6.2.4 Inclusion criteria

The included participants were those who agreed to receive the mobile app, signed consent, those who could understand English or French, and owned a smartphone capable to receiving the oral health education App.

6.2.5 Exclusion criteria

The participants who did not sign the consent form, patients under 18 years, and those having a learning disability.

6.2.6 Measurements

We evaluated the feasibility and acceptability of the BrushDJ mobile App using a structured questionnaire. The questionnaire was adapted from reported studies.[21, 22] The adaptations were done to make the questions applicable for users' perceptions of the App's impact on their homecare oral health practices.

Demographic details were collected, with respondents being asked to provide information on their age, gender, and education level as well as their oral health habits. Additional details regarding App usage were also assessed. This included their perceptions, experiences and likeability of the App and its usefulness during the study period. A standard 5-point Likert scale was employed to measure these items, with responses ranging from Strongly disagree (+1) to Strongly agree (+5). The scoring was done on all questions and was analysed by combining all questions to obtain a total, which was converted to a percentage. An arbitrary cut-off points were set, where a score less than 70% was classified as 'Less acceptable' /"Less feasible", and a score of 70% and above indicated 'Highly acceptable'/ 'Highly feasible'[23].

Ten items concerning the App's likability and engagement (its acceptability) were evaluated using the Likert scale. A composite variable was created by summing the scores of these ten items. The reverse scoring was done on five questions, and then acceptability was analysed by combining all questions to obtain a total score of 50 (100%). A score less than 70% was classified as 'Less acceptable', and a score of 70% and above indicated 'Highly acceptable'.

Feasibility was assessed using a standard 5-point Likert scale, with response options ranging from Strongly disagree (+1) to Strongly agree (+5). The analysis was done by combining all questions to calculate a total score of 65 (100%). A score less than 70% was considered "Less feasible", while a score above 70% was considered "Highly feasible".

The items were pilot-tested with ten individuals. This involved having participants complete the entire survey and then discussing each item with them to ensure that the items were clearly written, understandable, and interpreted as intended. The general Cronbach alpha for the entire sample on acceptability variables was 0.712 and 0.961 for feasibility.

6.2.7 Procedure

A total of 111 adult participants received the BrushDJ mobile oral health App and were asked to use the app at home for a period of three months. The BrushDJ oral health App is designed to motivate users to brush their teeth effectively. The App provides basic oral health education through videos, text, and pictures tailored for various age groups. Its primary focus is to enhance users' oral hygiene by demonstrating appropriate techniques. Once BrushDJ is downloaded, it can be used offline without the need for a regular internet connection. However, during installation, participants were given an internet package for three months, even though they could access the App regularly without needing internet. At the end of the three months of using the App, an online structured questionnaire was used to collect data. The group who used WhatsApp received the questionnaire on their smartphone and filled in data in Google form. For those who were not available for the WhatsApp online follow-up data collection, a telephonic interview was conducted.

6.2.8 Data analysis

Analysis was conducted using Stata software version 16 (StataCorp, College Station, TX). Descriptive statistics, such as frequency and percentage distributions, were employed to assess the feasibility and acceptability of the mobile oral health App. Bivariate analysis using the Chi-square test was performed to measure the level of association between demographic characteristics and the mobile oral health App acceptability and feasibility. The significance level was established at 0.05, with a 95% confidence interval.

6.3 RESULTS

6.3.1 Demographic characteristics of the participants

The response rate was 81%, with 90 out of 111 participants taking part in the study. The age category 18-27 years was predominant, and over half of the participants were male 51.11% (n=46). Most of the participants 68.89% (n=62) had completed high school level of education (Table 6.1).

Table 6. 1 Demographic characteristics of the participants

Demographics(n=90)	Frequency	Percentage
Age		
18-27 years	40	44.44
28-37 years	28	31.11
38-47 years	13	14.44
48-57 years	7	7.78
58 and above	2	2.22
Gender		
Male	46	51.11
Female	44	48.89
Level of education		
Less than high school	5	5.56
High school	62	68.89
College or university up to bachelor	22	24.44
College or university up to master or PhD	1	1.11

6.3.2 Frequency and percentage distribution of oral hygiene behaviour

The majority of the participants brush their teeth twice a day, in the morning and at night, before going to bed (88.89%, n=80). Just over a third of participants use dental floss every day (36.67%, n=33), and most of them thought that regular oral cleaning, brushing teeth, and interdental cleaning are important (95.51%, n=85) (Table 6.2).

Table 6. 2 Frequency and percentage distribution of oral hygiene behaviour

Habitual variables on oral hygiene	Yes n (%)	No n (%)
I brush my teeth when I wake up and before going to bed every day.	80 (88.89)	10 (11.11)
I clean my teeth (brush or rinse with water) after meals.	79 (87.78)	11 (12.22)
I use floss to clean my teeth every day.	33 (36.67)	57 (63.33)
I use an interdental brush to clean my teeth every day.	29 (32.22)	61 (67.78)
I think regular oral cleaning (brushing and interdental cleaning) is important.	85 (95.51)	4 (4.49)
I think I have good oral health.	71 (78.89)	19 (21.11)

6.3.3 Oral health app acceptability among the participants

Over half of the participants strongly agreed that they liked to use the App frequently, found the App not complex, think that they would not need the support of a technical person to be able to use the App and imagine that most people would learn to use the App very quickly (Table 6.3).

Table 6. 3 Distribution of oral health App acceptability among the participants

Oral health App acceptability assessment(usability)	Strongly disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly agree n (%)
I think that I would like to use this App frequently.	1 (1.11)	5 (5.6)	1 (1.1)	26 (28.9)	57 (63.3)
I found the App unnecessarily complex.	45 (50)	23 (25.56)	3 (3.33)	11 (12.22)	8 (8.89)
I thought the App was easy to use.	7 (7.78)	6 (6.67)	6 (6.67)	32 (35.56)	39 (43.33)
I think that I would need the support of a technical person to be able to use this App.	46 (51.11)	25 (27.78)	4 (4.44)	7 (7.78)	8 (8.89)
I found the various functions in this App were well integrated.	2 (2.22)	0	9 (10)	38 (42.22)	41 (45.56)
I thought there was too much inconsistency in this App.	36 (40)	35 (38.89)	8 (8.89)	8 (8.89)	3 (3.33)
I imagine that most people would learn to use this App very quickly.	3 (3.33)	7 (7.78)	4 (4.44)	30 (33.33)	46 (51.11)
I found the App very cumbersome to use.	41 (45.56)	33 (36.67)	3 (3.33)	8 (8.89)	5 (5.56)
I felt very confident using the App.	6 (6.67)	2 (2.22)	7 (7.78)	34 (37.78)	41 (45.56)
I needed to learn a lot of things before I could get going with this App.	34 (37.78)	29 (32.22)	4 (4.44)	13 (14.44)	10 (11.11)

6.3.4 Oral health mobile App feasibility among the participants

Most of the participants strongly agree that they like the oral care video in the App, which helps them learn more about oral cleaning, and most of the participants confirm that the App is very useful (Table 6.4).

Table 6. 4 Frequency and percentage distribution on the feasibility of oral health App

Oral health App feasibility	Strongly disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly agree n (%)
I like the oral care video, which teaches me more about oral cleaning.	0	0	2 (2.22)	34 (37.78)	54 (60)
I like the App pointing out the focal areas in my mouth, which requires extra care.	0	0	5 (5.56)	47 (52.22)	38 (42.22)
I like the App showing the focal areas that require extra cleaning effort in the dental chart.	0	0	7 (7.78)	47 (52.22)	36 (40)
I like the App reminding me to use dental floss and an interdental brush to clean my teeth.	5 (5.56)	1 (1.11)	18 (20)	33 (36.67)	33 (36.67)
I like the App user manual, it makes the App easy to use.	9 (10)	4 (4.44)	23 (25.56)	21 (23.33)	33(36.67)
I like the App rewarding with applause when achieving a toothbrushing session.	18(20)	3 (3.33)	9 (10)	33 (36.67)	27 (30)
I like that the App provides important information about oral health.	3 (3.33)	1 (1.11)	6 (6.67)	28 (31.11)	52 (57.78)
I like the App allowing me to set reminders for tooth brushing.	11 (12.22)	2 (2.22)	6 (6.67)	36 (40)	35 (38.89)
I like the App reminding me to brush my teeth according to the time that is set.	11 (12.22)	2 (2.22)	6 (6.67)	31 (34.44)	40 (44.4)
I like the App reminding me to clean my teeth at least twice a day.	10 (11.11)	2 (2.22)	4 (4.44)	33 (36.67)	41 (45.56)
I like the App showing the progress of tooth brushing with an arrow, which directs me to brush my teeth in the same order.	0	0	6 (6.67)	33 (36.67)	51 (56.67)
I like the background music played in the App during the toothbrushing session.	13 (14.44)	5 (5.56)	6 (6.67)	38 (42.22)	28 (31.11)
The App was useful.	1 (1.11)	1 (1.11)	2 (2.22)	23 (25.56)	63 (70)

6.3.5 The association between mobile App acceptability, feasibility and demographic characteristics

Table 6.5 shows the association between the App acceptability, feasibility, age group, gender and level of education. In terms of acceptability, the app was found to be highly acceptable by the majority across all age groups, though there were variations. Participants aged 18-27 years showed the highest rate of acceptability (92.5%), whereas those aged 48-57 years had the lowest (71.43%). The differences in acceptability among age groups were not statistically significant ($p=0.415$). However, the app's feasibility varied more notably by age. Younger participants (18-27 years) reported higher feasibility (82.5%) compared to older participants (48-57 years), who found it less feasible (42.86%), with a statistically significant difference ($p=0.013$).

Gender did not significantly impact acceptability or feasibility, with both male and female participants showing similar levels of high acceptability and feasibility ($p=0.126$ for acceptability and $p=0.623$ for feasibility). Education level significantly influenced both acceptability and feasibility. Participants with less than a high school education found the app less acceptable (20%) and less feasible (40%), compared to those with higher education levels, where acceptability and feasibility rates were notably higher. High school graduates showed an 90.32% acceptance rate, and those with college or university education up to a bachelor's degree had a 95.45% acceptance rate. The differences in acceptability and feasibility across education levels were statistically significant ($p=0.000$ for acceptability and $p=0.038$ for feasibility).

Table 6. 5 Oral health App overall acceptability and feasibility among the participants by demographic characteristics

	Less acceptable n (%)	Highly acceptable n (%)	P value	Less feasible n (%)	Highly feasible n (%)	P value
Age group						
18-27 years	3(7.5)	37(92.5)	0.415	7 (17.5)	33(82.5)	0.013
28-37 years	5 (17.86)	23 (82.14)		1 (3.57)	27 (96.43)	
38-47 years	1(7.69)	12 (92.31)		2 (15.38)	11(84.62)	
48-57 years	2 (28.57)	5 (71.43)		4 (57.14)	3 (42.86)	
58 and above	0	2 (100)		0	2 (100)	
Total	11 (12.22)	79 (87.78)		14 (15.56)	76 (84.44)	
Gender						
Male	8 (17.39)	38 (82.61)	0.126	8 (17.39)	38 (82.61)	0.623
Female	3 (6.82)	41 (93.18)		6 (13.64)	38 (86.36)	
Total	11 (12.22)	79 (87.78)		14 (15.56)	76 (84.44)	
Level of education						
Less than high school	4 (80)	1 (20)	0.000	3 (60)	2 (40)	0.038
High school	6 (9.68)	5 (90.32)		9 (14.52)	53 (85.48)	
College or university up to bachelor	1 (4.55)	21 (95.45)		2 (9.09)	20 (90.91)	
College or university up to master or PhD	0	1 (100)		0	1(100)	
Total	11 (12.22%)	79 (87.78)		14 (15.56)	76 (84.44)	

6.4 DISCUSSION

This study was the first to evaluate the feasibility and acceptability of a mobile App for oral health education among the adult population in Rwanda. The results of our study indicate strong support for the alternate hypothesis (H_a), which posits that the mobile application was both feasible and acceptable for oral health education among adults in Rwanda. This study showed that the acceptability and feasibility of the mobile app were higher among younger participants and were also influenced by education level, with those having less than a high school education reporting lower acceptability and feasibility compared to those with higher education. The predominating age group in our study finding was contrary to Underwood and colleagues,[8] who reported higher participation of 7-12 years age group in their study. The age group differences may be attributed to the sample selection of our study being limited to adults who were 18 years and above. Numerous mobile applications focused on preventing tooth decay primarily emphasize the promotion of effective oral hygiene habits and are tailored towards the young adult population.[24] The younger age group in our study were the 18-27 years old, and different educational attainment measured by levels of education did influence the usage patterns of mobile App. Different results were reported in India, where individuals' education level was not related to the usage of mobile applications for assistance with oral health care.[11] Hedge and colleagues have found that low literacy rates negatively affected the ability to read the information channelled through mobile phones.[5] The study conducted in Kenya revealed findings similar that low literacy rates negatively affected the ability to read the information channelled through mobile phones.[25] Future larger studies are warranted to study how these exposure factors may influence the use of mobile oral health App in this setting, more so that age and gender have been evidence to influence individuals' information processing.[26] The participants in the present study reported good oral hygiene behaviours and positive attitudes, although there is room for improvement on some behaviours, such as use of interdental hygiene aides.

The participants in our study demonstrated a high level of acceptability of the mobile oral health App, which is slightly higher than the 73.7% reported in Boston and 77% reported in Malaysia.[27, 28] High acceptability of the mobile App implies intention to use the App as reported by Venkatesh et al.[26] thus, our finding signals hope for the App usage. Low acceptability of the mobile App can indicate poor popularity, and has been reported that it can affect the utilization.[29] The high acceptability of the mobile App is commendable as it has resulted in frequent home use of the App

in other settings[30] and, therefore, presents hope in oral health education and home care procedures to eliminate oral disease.

The strong agreement with frequent App usage aligns with research in the field of user acceptance of technology, which emphasizes the importance of perceived usefulness as a key determinant of adoption. Studies based on the Technology Acceptance Model have consistently found that users are more likely to adopt a technology if they perceive it as useful.[31] The high proportion of participants expressing a desire for frequent App usage in our study suggests that they perceive the App as valuable and relevant to their needs, which is consistent with Technology Acceptance Model. The finding that participants did not find the App complex and believed they would not need technical support to use it echoes the importance of perceived ease of use in technology adoption. According to Technology Acceptance Model, perceived ease of use influences users' attitudes towards and intentions to use a technology.[31] Research has shown that users are more likely to adopt technologies that are perceived as easy to use.[32] Therefore, the absence of perceived complexity and the belief that technical support would not be necessary by the participants in our study suggests that the App is intuitive and user-friendly, which are critical factors in encouraging adoption.

Participants in our study believed that most people would quickly become adept at using the App, indicating positive perceptions of the App's learnability. This aligns with research emphasizing the importance of perceived ease of learning in technology acceptance.[32] When users believe that a technology is easy to learn, they are more likely to adopt it and perceive it positively. In our study, it was observed that participants expressed a high level of confidence in utilising the mobile oral health App. The participants reported that the various features within the application were seamlessly integrated and user-friendly. Our observations align with the previously reported study, which indicated that individuals utilising oral health applications on their mobile devices exhibit great enthusiasm in endorsing and discussing their experiences.[33] This enthusiasm further extends to encouraging others to utilise the application, primarily due to its user-friendly interface.

Almost 85% of the participants in our study found the mobile App for oral health education to be feasible and usable. These results are commendable because it means the participants were able to navigate the App, understand the contextual meaning of the text and respond to the contents in the App. Feasibility of a programme or project is one of the initial steps necessary before a roll-out of

a programme. According to Nicholas and Chinedum in 2017, feasibility determination is important to determine if a proposed programme or, project, service or business will be successful.[34] The high feasibility findings in our study reflect the positive reception of the mobile application among participants, indicating its potential to deliver oral health education effectively. Similar results were observed in a study involving the elderly, where mobile-based video education programs were found to be beneficial and effective. These programs improved patients' knowledge, satisfaction with education, and implementation of the educational content, ultimately enhancing their oral health.[35]

The overwhelming agreement regarding the oral care videos by the participants in our study suggests that the participants found them informative and engaging. This aligns with previous research highlighting the effectiveness of multimedia interventions, such as videos, in promoting health education and behaviour change.[36] The videos likely served as valuable educational tools, providing visual demonstrations of proper oral hygiene practices and enhancing participants' understanding of oral care techniques. Participants in our study reported that they liked the reminders within the App, which prompt them to brush their teeth twice a day and perform interdental cleaning using dental floss or an interdental brush. The App reportedly conveyed valuable oral health information, and this creates hope that it may be a great tool for oral health awareness. Mobile Apps for oral health education are useful for adults, adolescents, and children because it has been shown that the information provided through smartphones by parents positively impacts children's oral health awareness.[11, 37] Feasibility determination is needed for the growth of the programme to advocate for its continuance.[34] Since mobile Apps are useful, they should be promoted, and their messages should be designed according to the end users. In addition, the content should be theoretically grounded and empirically validated.[38]

The limitations of our study include its cross-sectional design and the fact that it focused exclusively on a specific group of participants in Rwanda. As a result, the findings may not reflect the broader views of the entire population of Rwanda regarding mobile Apps for oral health education. Therefore, it is essential to consider that some people may be receptive to using mobile Applications, whereas others might opt to maintain with the conventional clinical care offered in dental clinics. Moreover, the sample size and location do not represent the entire city, which limits the generalizability of the findings. Additionally, the feasibility data were exclusively obtained through the survey questionnaire given to participants who used the BrushDJ App. Future

extensive studies should include a more direct evaluation of the preferences of different oral health practitioners regarding the App's features alongside other oral health outcomes experienced by patients receiving the interventions to assess the effectiveness of the App.

6.5 CONCLUSIONS

Our study found that the acceptability and feasibility of mobile App for oral health education (BrushDJ) was high among the study participants. The mobile App for oral health received positive reviews from the user-friendliness nature. Our study findings have highlighted that the mobile App for oral health (BrushDJ) is a useful tool that might contribute to behaviour change and the adoption of adequate oral health measures. Population groups of all ages and backgrounds, even those in remote areas where the accessibility to dental services is challenging, can use the mobile App for oral health education.

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CHAPTER 7

Discussion and Recommendations

This chapter presents the integrated discussion of this PhD from the key findings (Chapter 4 to 6) and have proposed recommendations to be considered for future oral health research, oral health policy and oral health practice in Rwanda. The chapter is divided into 5 sections. Section 7.1 provide the introduction. Section 7.2 specify and discuss the summary of the key findings. Section 7.3 highlights the scholarly contributions and the policy impact of the PhD. Section 7.4 contains the recommendations for future research. Section 7.5 presents the conclusions from the PhD Studies.

7.1 INTRODUCTION

This mixed methods PhD study has generated new knowledge on oral health knowledge, attitude and oral hygiene practices, evaluation of oral health services and challenges facing dental professionals in offering oral health services to the community. New knowledge also generated on the role of mobile app for oral health education in terms of feasibility and acceptability among adults in Nyarugenge district, Rwanda. The high burden of oral diseases had been reported globally [1]. The commonly reported oral diseases are dental caries and periodontal diseases which was found to be a strongly associated with poor oral health behaviour[2, 3].The Rwanda oral health survey found poor oral health status among community with 70% of individuals not utilizing oral health services while majority of adults were reported to have oral debris and dental calculus[4]. Oral diseases are still a burden in Rwandan communities as indicated by previous studies[4-6]. The finding of my PhD study has shown the lack of oral health knowledge and poor oral practices in the community[7]. Furthermore, it has reported on challenges that the oral health professionals (OHPs) are faced with when providing dental services to the communities in Nyarugenge, Rwanda[8]. Moreover, the availability of dental materials and instruments in the dental facilities and the considerations human resources to address OHPs-to-patient ratio will enhance better service provision. Our findings underscore the need for health policy makers to develop proactive strategies that prioritize prevention of oral diseases. Such strategies have been recommended by our findings to be homebased oral health promotions using mobile App oral health education to promote oral health behaviour[9].

7.2 KEY FINDING AND DISCUSSION

7.2.1 Summary of key findings

The key findings of my PhD are summarized in Table 7.1 and discussed below.

Table 7. 1 Key PhD findings

Key PhD findings
• Poor oral health knowledge was found in 42% (n=179) of the participants. • Poor oral health practices were found in 67.37% of the participants while 12.44% (n=53) showed poor oral health attitudes.
• The OHPs said that it is almost impossible to give oral health education to every patient they examine due to the heavy workload. • The OHPs reported that they do not have sufficient equipment, instruments, or materials to offer dental care to the community. • Lack of dental assistants and poor oral professionals to patient's ratio. • The adequacy was low concerning the ultrasonic unit (n = 3; 42.86%) and ultrasonic scaler tips were inadequate. • Only two (28.57%) health facilities had a demonstration model, toothbrush, and dental floss for interdental cleaning during oral hygiene instruction. • None of the health facilities used a mobile application for oral health education.
• The mobile App oral health education was found to be highly acceptable at 87.78% (n=79) among the participants. • The mobile App for oral health education was highly feasible at 84.44% (n=76) for the majority of the participants.

7.2.2 Oral health knowledge, attitude, and oral hygiene practices

My PhD study was among the first to report data on oral health knowledge, attitudes, and oral hygiene practices of adult participants in Nyarugenge, Rwanda[7] . Poor oral health knowledge was found in 42% of the participants, indicating that a substantial portion of the population lacks adequate understanding of oral health principles. This finding underscores the importance of educational interventions to improve public knowledge about oral hygiene, dental care, and the consequences of poor oral health.

The high prevalence (67.37%) of poor oral health practices among the participants is alarming as it suggests a widespread failure to adopt recommended oral hygiene behaviors such as regular brushing, flossing, and dental check-ups. Poor oral health practices can lead to various oral health problems including cavities, gum disease, and tooth loss[1, 10, 11], highlighting the need for targeted interventions to promote better oral hygiene habits.

The finding that 12.44% of participants exhibited poor oral health attitudes indicates a subset of individuals may hold beliefs or attitudes that contribute to neglecting oral health. These attitudes could include beliefs about the importance of oral hygiene, perceptions of dental care, or cultural factors influencing oral health behaviors. Addressing these attitudes through education and awareness campaigns may help improve overall oral health outcomes.

Further analysis could explore potential factors contributing to the observed patterns of poor oral health knowledge, practices, and attitudes. Socioeconomic status, educational background, access to dental care, cultural beliefs, and personal habits are among the factors that could influence oral health behaviors. Understanding these factors can inform the development of targeted interventions to address specific barriers to oral health.

The findings from this PhD on oral health knowledge, attitude, and oral hygiene practices underscore the importance of public health initiatives aimed at promoting oral health literacy, improving access to dental care, and fostering positive attitudes toward oral hygiene. Educational programs targeting both individuals and communities can play a critical role in raising awareness about the importance of oral health and encouraging the adoption of healthy oral hygiene practices. The ecological model posits that intrapersonal factors, such as biological and psychological factors; interpersonal factors, such as social support from friends or family members;

organisational factors comprise health system factors; community encompasses cultural factors or norms and policy influence the behaviour of interest[12]. The use of ecological model for this PhD conceptual framework has revealed that several factors can be linked together to influence better health outcome[13]. The findings on oral health knowledge, attitudes, and oral hygiene practices of adult participants in Nyarugenge, Rwanda are explained according to the conceptual framework as follow:

At the individual level, education, socioeconomic status, personal beliefs, and attitudes significantly influence oral health knowledge, practices, and attitudes. Those with lower education levels or socioeconomic status may face barriers to accessing oral health information and resources, resulting in inadequate oral health knowledge and practices. Likewise, individuals with negative attitudes toward oral health may be less inclined to participate in preventive measures like regular brushing and dental check-ups.

Interpersonal relationships and social networks also impact oral health behaviors. Family members, friends, and peers can provide information, support, or encouragement for maintaining good oral hygiene habits. Conversely, social norms within communities or social circles may contribute to the adoption of unhealthy behaviors or attitudes towards oral health. For example, cultural beliefs or social norms might discourage seeking dental care or prioritize other health concerns over oral health.

The community environment includes factors such as the availability of dental care services, oral health education programs, and other resources that support oral health. Communities with restricted access to dental care or preventive services may see higher rates of poor oral health outcomes due to obstacles in receiving treatment and preventive care. Moreover, community-based interventions, such as school-based oral health education programs, mobile health apps, and community dental clinics, can enhance oral health knowledge and practices among the population.

Organizations such as schools, workplaces, healthcare facilities, and community-based groups contribute to promoting oral health through various policies, programs, and services. Schools can incorporate oral health education into their curricula, while workplaces might offer incentives for employees to engage in preventive dental care. Healthcare facilities can provide accessible and affordable dental services, especially for individuals in underserved communities.

Government policies and regulations establish the broader socio-political framework affecting oral health behaviors. Policies on healthcare financing, public health initiatives, community water fluoridation, and regulations regarding oral hygiene products can influence population-level oral health outcomes. Effective policies that emphasize preventive care and address social determinants of health can help reduce disparities in oral health outcomes across different groups.

7.2.3 Oral health services and challenges faced by oral health practitioners

The findings of our study showed that OHPs found it almost impossible to provide oral health education to every patient due to heavy workloads. This underscores a significant barrier to preventive care provision by OHPs to individuals in the community. Adequate oral health education is crucial for promoting good oral hygiene practices and preventing dental problems. The inability to allocate sufficient time for education may result in missed opportunities to empower patients with essential knowledge and skills for maintaining oral health. The shortage of dental assistants and high OHP-to-patient ratio exacerbates the challenges faced by OHPs in delivering dental care. Insufficient staffing levels can lead to increased workload, reduced efficiency, and compromised quality of care. Addressing staffing shortages and optimizing OHP-to-patient ratios are essential to improve the accessibility and quality of dental services provided to the community.

The reported lack of necessary equipment, instruments, and materials poses a significant obstacle to providing comprehensive dental care to the community. Lacking access to essential resources, OHPs may struggle to perform necessary dental procedures effectively, which might compromise oral health outcomes among patients. Adequate investment in dental infrastructure is essential to address these resource constraints and ensure quality care delivery.

The low adequacy concerning the ultrasonic unit and inadequate ultrasonic scaler tips highlight deficiencies in equipment maintenance and quality control. Proper maintenance and calibration of dental equipment are crucial for ensuring accurate diagnosis and effective treatment. Additionally, ongoing training and professional development are essential to equip OHPs with the necessary skills and knowledge to use dental equipment effectively and safely. The limited availability of demonstration models, toothbrushes, dental floss, and the absence of mobile applications for oral health education signify gaps in educational resources and technological solutions. Access to educational materials and innovative tools, such as mobile applications, can enhance patient

engagement, promote self-management of oral health, and facilitate the delivery of tailored educational content to diverse populations.

The Conceptual framework model used in this PhD is well aligned to these finding as follow:

At the individual level, heavy workloads hinder OHPs' ability to provide comprehensive oral health education to every patient they examine. This constraint may lead to variations in the quality and depth of education received by patients, impacting their knowledge and behaviors related to oral health maintenance.

Interpersonal Level: Interactions between OHPs and patients are influenced by the availability of resources such as equipment, instruments, and materials. The reported lack of sufficient resources limits the scope and effectiveness of dental care services provided to the community, potentially affecting patient satisfaction and treatment outcomes.

Community Level: The community context plays a crucial role in shaping the availability and accessibility of oral health services. The shortage of dental assistants and OHPs-to-patient ratios reflect broader systemic issues within the healthcare system, including workforce shortages and resource allocation disparities, which may disproportionately affect underserved communities.

Organizational Level: Organizational factors, such as the adequacy of equipment and training, directly impact the capacity of healthcare facilities to deliver quality dental care. The low adequacy concerning the ultrasonic unit and inadequate scaler tips highlight deficiencies in equipment maintenance and quality control, which may compromise patient safety and treatment efficacy.

Policy Level: Policy decisions related to healthcare financing, workforce planning, and resource allocation shape the overall landscape of oral health services. The absence of mobile applications for oral health education reflects a missed opportunity to leverage technology for improving health literacy and promoting preventive care at the population level.

By considering these challenges through the lens of the ecological model, it becomes evident that addressing systemic barriers to oral health requires a multifaceted approach that encompasses interventions at multiple levels of influence.

Strategies to improve oral health education and care delivery may include:

Implementing policies to address workforce shortages and improve staffing ratios, particularly in underserved areas.

Investing in dental infrastructure and equipment maintenance to ensure the availability of necessary resources for providing quality care.

Promoting the integration of technology, such as mobile applications, into oral health education efforts to enhance accessibility and reach diverse populations.

Collaborating with community stakeholders to develop culturally sensitive and contextually relevant oral health programs that address the unique needs of local populations.

7.2.4 The feasibility and acceptability of a mobile App for oral health education

The results indicating high acceptability (87.78%) and feasibility (84.44%) of a mobile App for oral health education among participants suggest promising opportunities for leveraging technology to improve oral health outcomes.

The high acceptability of the mobile App for oral health education suggests that participants are receptive to utilizing technology as a means of accessing oral health information and resources. This finding aligns with previous research indicating the growing acceptance of mobile health interventions for promoting health behaviors and outcomes[14]. Factors contributing to the acceptability of the mobile App may include its user-friendly interface, accessibility, relevance of content, and perceived effectiveness in delivering oral health education. Additionally, the convenience of accessing educational resources anytime, anywhere through a mobile device may enhance its appeal to participants.

The high feasibility of the mobile App indicates that participants perceive it as a practical and viable tool for delivering oral health education. Feasibility encompasses factors such as usability, accessibility, scalability, and cost-effectiveness of the intervention. The feasibility of the mobile App may be attributed to its ability to overcome barriers associated with traditional methods of oral health education, such as limited access to healthcare facilities or oral health professionals. The mobile App provides a convenient and accessible platform for delivering educational content to a wide audience, potentially reaching individuals who may otherwise have limited access to oral health resources.

The findings underscore the potential of mobile health technologies in advancing oral health promotion efforts. Mobile Apps can serve as effective tools for disseminating evidence-based oral health information, promoting positive oral hygiene behaviors, and empowering individuals to take proactive steps towards improving their oral health. Integrating mobile health interventions into existing oral health programs and initiatives may enhance their reach, effectiveness, and sustainability. By leveraging the ubiquity of mobile devices and the increasing digital literacy among populations, healthcare providers and policymakers can capitalize on the potential of mobile technology to address oral health disparities and improve population-level oral health outcomes.

Linking the mobile App for oral health education with the conceptual framework model that guided this PhD, we found that a mobile App for oral health education among participants align well with various levels of influence on health behaviors and outcomes.

At the individual level, the high acceptability of the mobile App suggests that participants find it personally relevant and useful for their oral health needs. Participants have perceived the App as an accessible and convenient way to access educational resources and information about oral health. The feasibility of the mobile App indicated that participants believed it is practical and achievable to use the App for oral health education. This perception may be influenced by factors such as the user-friendly interface, ease of navigation, and compatibility with their mobile devices.

Interpersonal relationships and social networks can influence individuals' attitudes and perceptions towards health interventions. The high acceptability of the mobile App may be influenced by positive word-of-mouth recommendations from peers, family members, or healthcare providers who have used or endorsed the App. Interpersonal factors, such as social support and encouragement, may contribute to the perceived feasibility of using the mobile App for oral health education. Individuals may feel more confident in their ability to use the App if they receive support or guidance from others in their social network.

Community norms and values regarding the use of technology and health promotion efforts can impact individuals' acceptance of the mobile App. If the App aligns with community preferences and expectations for accessing health information, it is more likely to be accepted and adopted by a larger proportion of the population. Community resources and infrastructure, such as access to mobile devices and internet connectivity, influence the feasibility of using the mobile App for oral

health education. Communities with better access to technology and digital resources may perceive the App as more feasible and accessible.

Organizational factors, such as the availability of funding and support for health promotion initiatives, can influence the acceptability of the mobile App within healthcare settings. If healthcare organizations endorse and promote the use of the App, it may increase its acceptability among patients and providers. Organizational policies and practices related to technology adoption and implementation impact the feasibility of integrating the mobile App into existing oral health education programs. If organizations provide training and support for using the App, it enhances its feasibility for both patients and healthcare providers.

Policy factors, such as the involvement of policymakers in decisions related to health information technology and digital health initiatives, can shape the broader context in which the mobile app operates. Supportive policies that prioritize investment in digital health infrastructure and encourage the use of mobile apps for health promotion can enhance both the acceptability and feasibility of the app.

In conclusion, the high acceptability and feasibility of the mobile App for oral health education among participants reflect its alignment with individual preferences, interpersonal dynamics, community norms, organizational practices, and policy priorities. By addressing factors at multiple levels of influence, healthcare organizations and policymakers can maximize the potential of mobile health technologies to improve oral health behaviors and outcomes within communities.

7.3 SCHOLARLY CONTRIBUTION OF THE PHD STUDY

7.3.1 Generating new knowledge

Study 1 has generated new knowledge on oral health knowledge, attitude, and oral hygiene practices in Nyarugenge District, Rwanda[7]. This information is essential for prioritizing resources and designing interventions to address oral health disparities.

Study 2 was the first comparative analysis of the healthcare facilities for the provision of preventive oral health services offered in Nyarugenge District. Moreover, It generated knowledge on perspectives and challenges faced by oral health professionals in rendering oral health services in Nyarugenge District[8].

Study 3 contribute new knowledge on the feasibility and acceptability of the use of mobile App for oral health education on improving oral health knowledge, attitude, and oral hygiene practices in Nyarugenge District of Rwanda. It was one of the first studies to be done in the country of Rwanda[9].

7.3.2 Methodological innovation

Studies 1 was among the first study to evaluate oral health knowledge, attitude, and oral hygiene practices. The baseline data obtained can be used by the researchers and policymakers to tailor interventions that address the specific challenges identified in the study population.

Study 2 is the first to evaluate oral health services and explore challenges facing dental professional in offering oral health services in Rwanda. The findings can be used to improve management and care.

Study 3 obtained data on feasibility and acceptability of mobile App for oral health education could contribute to health policy and health care system intervention that can lead to improvements of oral health self-care of individuals at home through the introduction of a mobile App for oral health education.

7.4 RECOMMENDATIONS FROM THE PHD STUDIES

7.4.1 Recommendation for future research

- Evaluation of the feasibility and acceptability of the mobile App for oral health education on a larger sample size that can be representative of the whole Rwanda.
- To evaluate the efficacy of the mobile Apps on a larger sample size using implementation approach, as our study has indicated their feasibility and acceptability within the community in Nyarugenge district.
- The use of implementation research approach is recommended for future studies.
- Development of a mobile App for oral health education within the context of the Rwanda population.
- The Rwanda oral health surveys to incorporate of oral health knowledge, attitudes and oral health practices of the population.
- Future studies should include studies for scaling the mobile app initiative, training community health workers, and improving the oral health service infrastructure to support preventive care

- The reliability testing for the KAP tool is a limitation. The tool was used and validated in a prior study and could have been tested for the current setting. The future studies in the same setting are recommended.

7.4.2 Recommendations for policy and practice

Individual Level:

- Recommend the Rwanda Dental Association to motivate dental professionals to provide oral health education to patients.
- Recommend the Ministry of Health (MOH) and hospitals to support mobile app-based oral health education, as these apps are feasible and accepted by the community.
- Recommend MOH to facilitate the inclusion of interdental cleaning and mouthwash in insurance coverage.

Interpersonal Level:

- Recommend health facilities to maintain regular community outreach to promote oral health education.
- Recommend the Ministry of Education to incorporate oral health education into the curriculum to enhance knowledge from an early age.

Organizational Level:

- Recommend hospital administration to ensure the availability of dental equipment and materials on site and to involve dental professionals in the procurement process.
- Recommend MOH to regularly conduct audits to assess the availability, functionality, and adequacy of dental equipment and materials.
- Recommend hospital administration to involve dental professionals in procurement of dental materials.

Community Level:

- Recommend the Ministry of ICT to support free access to trusted oral health apps to improve community oral health.

Policy Level:

- Recommend MOH to continuously oversee, contribute to, and facilitate oral health education in the community.

7.5 CONCLUSIONS

In conclusion, the results of this study reveal a multifaceted landscape of challenges and opportunities in oral health education and care delivery. The findings underscore the prevalence of poor oral health knowledge and practices among participants, indicating a need for targeted interventions to address these gaps. Additionally, the study highlights significant barriers faced by OHPs, including heavy workloads, inadequate resources, and staffing shortages, which hinder their ability to provide comprehensive dental care to the community. The inadequacy of equipment and educational resources, such as demonstration models and interdental cleaning tools, further complicates efforts to promote good oral hygiene practices. Moreover, the low utilization of mobile App for oral health education suggests a missed opportunity to leverage technology for improving health literacy and promoting preventive care.

However, amidst these challenges, the study also identifies a promising avenue for innovation and intervention because of the high acceptability and feasibility of a mobile App for oral health education among participants. This finding highlights the potential of technology-driven solutions in overcoming barriers to oral health promotion and education. By harnessing the power of mobile App, healthcare providers can reach a broader audience, deliver tailored educational content, and empower individuals to take proactive steps towards improving their oral health.

While the study highlights the significant challenges facing oral health education and care delivery, it also offers hope for the future through technological innovation. It is recommended that health system barriers be reduced to overcome disparities within the community, improve resource allocation for oral health services and delivery, and leverage technology to enhance oral health education outcomes. Collaborative efforts between healthcare organizations, policymakers, and stakeholders are essential for realizing the vision of improved oral health for all in Nyarugenge, Rwanda.

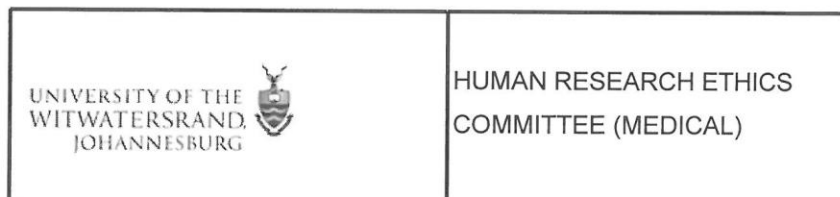
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APPENDICES

Appendix 1 Ethical approval from WITS HREC



Office of the Deputy Vice-Chancellor (Research and Innovation)

TO: Mr E Nzabonimana
School of Oral Health Sciences
Department of Community Dentistry
Dental School
University

E-mail: nzabaemmy@gmail.com

CC: Supervisor: Dr K Yolanda and Professor H Phumzile
<Yolanda.Kolisa@wits.ac.za>
and <HREC-Medical Research Office@wits.ac.za>

FROM: Mr Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2022/04/22

REF: R14/49

PROTOCOL NO: M220213 (This is your ethics application reference number. Please quote it in all enquiries, oral or written, relating to this study.)

PROJECT TITLE: *Oral health status in Nyarugenge District of Rwanda: the role of mobile application in oral health education*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to Government funding of the University.



MSWorks2000/Iain0007/Clearscan.wps



R49 Mr E Nzabonimana

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M220213

NAME:
(Principal Investigator)

Mr E Nzabonimana

DEPARTMENT:

School of Oral Health Sciences
Department of Community Dentistry
Dental School
University

PROJECT TITLE:

*Oral health status in Nyarugenge District of Rwanda:
the role of mobile application in oral health education*

DATE CONSIDERED:

2022/02/25

DECISION:

Approved unconditionally

CONDITIONS:

NOTE:

If contact information regarding student study participants is required,
please contact the Registrar's Office - <Nicoleen.Potgieter@wits.ac.za>

SUPERVISOR:

Dr K Yolanda and Professor H Phumzile

APPROVED BY:


Dr CB Penny, Chairperson, HREC (Medical)

DATE OF APPROVAL:

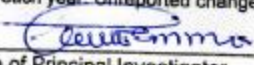
2022/04/22

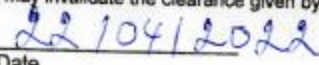
This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and ONE COPY returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg

I/we fully understand the conditions under which I am/we are authorized to carry out the above mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to submit details to the Committee. I agree to submit a yearly progress report. When a further requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in February and therefore reports and re-certification will be due in the month of February each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).


Signature of Principal Investigator


Date

Appendix 2 Ethical approval from Rwanda IRB



UNIVERSITY of
RWANDA

COLLEGE OF MEDICINE AND HEALTH SCIENCES
DIRECTORATE OF RESEARCH & INNOVATION

CMHS INSTITUTIONAL REVIEW BOARD (IRB)

Kigali, 5th/April/2022

Emmanuel Nzabonimana
School of Dentistry, CMHS, UR

Approval Notice: No234/CMHS IRB/2022

Your Project Title “*Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education*” has been evaluated by CMHS Institutional Review Board.

Name of Members	Institute	Involved in the decision		
		Yes	No (Reason)	
			Absent	Withdrawn from the proceeding
Prof Kato J. Njunwa	UR-CMHS	X		
Prof Stefan Jansen	UR-CMHS	X		
Dr Brenda Asimwe-Kateera	UR-CMHS	X		
Prof Ntaganira Joseph	UR-CMHS	X		
Dr Tumusiime K. David	UR-CMHS	X		
Dr Kayonga N. Egide	UR-CMHS	X		
Mr Kanyoni Maurice	UR-CMHS		X	
Prof Munyanshongore Cyprien	UR-CMHS	X		
Mrs Ruzindana Landrine	Kicukiro district		X	
Prof Gishoma Darius	UR-CMHS	X		
Prof Donatilla Mukamana	UR-CMHS	X		
Prof Kyamanywa Patrick	UR-CMHS		X	
Prof Condo Umutesi Jeannine	UR-CMHS		X	
Dr Nyirazinyoye Lactitia	UR-CMHS	X		
Dr Nkeramihigo Emmanuel	UR-CMHS		X	
Sr Maliboli Marie Josee	CHUK	X		
Dr Mudenge Charles	Centre Psycho-Social	X		

After reviewing your protocol during the IRB meeting of where quorum was met and revisions made on the advice of the CMHS IRB submitted on 30th March 2022, **Approval has been granted to your study.**

Please note that approval of the protocol and consent form is valid for **12 months**.

Email: researchcenter@ur.ac.rw

P.O Box 3286 Kigali, Rwanda

www.ur.ac.rw

You are responsible for fulfilling the following requirements:

1. Changes, amendments, and addenda to the protocol or consent form must be submitted to the committee for review and approval, prior to activation of the changes.
2. Only approved consent forms are to be used in the enrolment of participants.
3. All consent forms signed by subjects should be retained on file. The IRB may conduct audits of all study records, and consent documentation may be part of such audits.
4. A continuing review application must be submitted to the IRB in a timely fashion and before expiry of this approval
5. Failure to submit a continuing review application will result in termination of the study
6. Notify the IRB committee once the study is finished

Sincerely,



Assoc. Prof. Stefan Jansen
Ag. Chairperson Institutional Review Board,
College of Medicine and Health Sciences, UR

Date of Approval: The 5th April 2022

Expiration date: The 5th April 2023

Cc:

- Principal College of Medicine and Health Sciences, UR
- University Director of Research and Postgraduate Studies, UR

Appendix 3 Approval from National Health Research Committee

REPUBLIC OF RWANDA



MINISTRY OF HEALTH
P.O. Box 84 KIGALI
www.moh.gov.rw

Kigali, 19 MAI 2022
N°20/2707/DPMEHF/2022

NZABONIMANA Emmanuel
Principal Investigator
Tel:0783880746

Dear Sir,

Re: Authorization for research

Reference is made to your letter dated May 05th, 2022 requesting for authorization to conduct a research entitled: **“Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education”**;

Based on approvals from the College of Medicine and Health Science Institutional Review Board and the National Health Research Committee with reference No. 234/CMHS IRB/2022 and No. NHRC/2022/PROT/26 respectively;

I am pleased to inform you that the Ministry of Health has granted you the authorization to conduct this research according to the approved research protocol.

You are requested to share the results and to provide the final report to the Ministry of Health.

Sincerely,



Dr. NGAMIJE M. Daniel
Minister of Health

Cc:

- Hon. Minister of State in Charge of Primary Health Care
- Permanent Secretary/MoH
- Executive Administrator of Nyarugenge District

Appendix 4: Participants Information Sheet on oral health knowledge, attitude and practices

Title of the study: Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education

Introduction

Good day,

My name is Emmanuel Nzabonimana, and I am a Ph.D. student at the School of Oral Health Sciences at the University of the Witwatersrand in Johannesburg. Professor Phumzile Hlongwa and Dr Yolanda Malele-Kolisa supervise my research.

This information document will help you understand the study and why I am inviting you to participate. If you choose to participate, you will confirm that you understand the study and are doing so voluntarily. You will provide your approval by signing an informed consent declaration, and you will receive a copy for your records.

Why are we doing the study?

The study aims to determine the knowledge, attitude, and oral hygiene practices in Nyarugenge District, Rwanda. The information that will be collected will be used to create an effective guideline that will target improving oral health in Rwanda.

How will we do the study?

The study will be conducted through an interview and the questionnaire will be completed directly on the electronic device, and it will take about 10 minutes. We will ask you some of the questions related to oral health knowledge, attitude and practices. Your response will be recorded directly on the electronic device. Your name or your personal contact will not be recorded, and only general information will be needed for this study.

Will there be any harm from participating?

Participating in this study has no risks or harm. Only a checklist form will be used to collect appropriate data.

Will there be any benefits from participating?

There is no direct benefit from the study; only the general information gathered will be beneficial in setting policy and raising advocacy for oral health services.

Will I be paid?

There will be no payment upon participation in this study.

Voluntary consent

Participation is entirely voluntary. If you do not want to be part of this study, there will be no consequences for you.

How do I know that the information I give will be kept confidential?

The collected information will be kept private and confidential. If the findings from this study are published or presented at scientific conferences, your name and other personal means of identification will not be mentioned. In addition, the data collection tools will use codes for identification instead of names.

Confidentiality:

The confidentiality of the information you provide will be ensured as much as possible. Interviews will take place in a quiet and secured room containing only the researcher and the participant. Your consent form and your information will be kept in a research record created for you and they will be only accessible for the researchers.

Outputs

The results of this research will be communicated directly to the health centers. In addition, the findings will be shared with different policymakers in Rwanda. The results will be published in scientific journals. Later, the results will be presented in a thesis that will be submitted to the University of the Witwatersrand, Johannesburg, South Africa, for assessment. As per HPCSA guidelines, we will preserve the records of the data for a minimum of two years after the study results have been published or six years if there is no publication.

Who do I contact if I want to ask more questions?

We will be happy to answer any questions you have about this study. This research has been approved by the University of the Witwatersrand Research Ethics Committee and IRB Ethical Committee Rwanda. If you have any questions about your rights as a study participant, or questions or concerns about any aspect of the study, you may contact the Chairperson of the Ethics Committee, Professor Clement Penny, telephone number 011 717 2301 or by e-mail at Clement.Penny@wits.ac.za. If you have questions about the research, you may also contact the principal investigator: Emmanuel Nzabonimana telephone: +250783880746.

Thank you for your assistance with this study

Appendix 5: Participants Information Sheet for Dental professionals _ Qualitative data to explore challenges faced by oral health professionals in rendering oral health services to the community of Nyarugenge District

Title of the study: Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education

Introduction

Greeting,

My name is Emmanuel Nzabonimana, and I am a Ph.D. student at the School of Oral Health Sciences at the University of the Witwatersrand in Johannesburg. I'm doing study to explore challenges facing dental professionals in rendering oral health services to the community of Nyarugenge District. Professor Phumzile Hlongwa and Doctor Yolanda Malele-Kolisa are supervising my research work.

This information document will help you understand the study and invite you to participate. If you accept our invitation to participate in the study, you will be confirming that you understand the study and that you actively chose to participate. You will provide your approval by signing an informed consent declaration. You will receive a copy.

This interview will be recorded on audiotape and it will take about 30min to 45min. Your names will not be required; only codes will be used. I assure you that all responses received will only be used for scientific purposes within the framework of this survey.

Risks of being involved in the study

Participating in this study has no risks. However, during interview, you may feel uncomfortable with some questions and do not want to talk about them. In this event, you are not forced to provide information and you are free to not respond.

Benefits of being in the study

There is no direct benefit from the study; only the general information gathered will be beneficial in setting policy and oral guidance that will help the community in the future.

Payment for participation in research

There will be no payment made to the participant associated with this study.

Voluntary consent

Participation is entirely voluntary. If you do not want to be part of this study, there will be no consequence to you.

Privacy and anonymity

The collected information will be kept private and confidential. We guarantee that your voice will never be shared with anyone. The recorded interview will be transcribed and analyzed without mentioning your name. If the findings from this study are published or presented at scientific conferences, your name and other personal means of identification will not be mentioned. In addition, the data collection tools will use codes for identification instead of names.

Confidentiality:

The confidentiality of the information you provide will be ensured as much as possible. Interviews will take place in a quiet and secured room containing only the researcher and the participant. Your consent form and your information will be kept in a research record created for you and they will be only accessible for the researchers.

Outputs

The results of this research will be communicated to you at health centers. In addition, the findings will be shared with different policy makers in Rwanda. The results will be published in scientific journals. Later, the results will be presented in a thesis that will be submitted to the University of the Witwatersrand, Johannesburg, South Africa for assessment. As per HPCSA guidelines, we will preserve the records of the data for a minimum of two years after the study results have been published or six years if there is no publication.

Who do I contact if I want to ask more questions?

We will be happy to answer any questions you have about this study. This research has been approved by the University of the Witwatersrand Research Ethics Committee and IRB Ethical Committee Rwanda. If you have any questions about your rights as a study participant, or questions or concerns about any aspect of the study, you may contact the Chairperson of the Ethics Committee, Professor Clement Penny, telephone number 011 717 2301 or by e-mail at Clement.Penny@wits.ac.za. If you have questions about the research, you may also contact the principal investigator: Emmanuel Nzabonimana telephone: +250783880746.

Thank you for your assistance with this study

Appendix 6: Participants Information Sheet for Patients aged 18 years and older on feasibility and acceptability of a mobile application for oral health education among adults in Rwanda

Title of the study: Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education

Introduction

Good day. My name is Emmanuel Nzabonimana, and I am a Ph.D. student at the School of Oral Health Sciences at the University of the Witwatersrand in Johannesburg. The research work is supervised by Professor Phumzile Hlongwa and Doctor Yolanda Malele-Kolisa.

This information document will help you understand the study and why I am inviting you to participate. If you accept the invitation to participate in the study, you will be confirming that you understand the study and that you voluntarily chose to participate. You will provide your approval by signing an informed consent declaration. You will receive a copy.

Why are we doing the study?

The purpose of the study is to determine the feasibility and acceptability of a mobile application for oral health education among adults in Rwanda. The information collected will be used to enhance and adapt the use of mobile applications in oral health education in Rwanda.

How will we do the study?

After installing the BrushDJ mobile app for oral health education on your phone, you will use the app for a period of three months. At the end of the three-month period, you will receive an online questionnaire via WhatsApp. If you do not receive the WhatsApp link, you can also provide feedback via phone call. Please complete the questionnaire, which will take about 10 minutes to fill out, on your electronic device. The questions will focus on the feasibility and acceptability of the app. Your responses will be recorded directly on the device, and no personal contact information will be collected—only general information will be used for this study.

Will there be any harm from participating?

Participating in this study has no risks or harm. Only a checklist form will be used to collect appropriate data.

Will there be any benefits from participating?

There is no direct benefit from the study; only the general information gathered will be beneficial in setting policy and raising advocacy for oral health services.

Will I be paid?

There will be no payment upon participation in this study.

Voluntary consent

Participation is entirely voluntary. If you do not want to be part of this study, there will be no consequences for you.

How do I know that the information I give will be kept confidential?

The collected information will be kept private and confidential. If the findings from this study are published or presented at scientific conferences, your name and other personal means of identification will not be mentioned. In addition, the data collection tools will use codes for identification instead of names.

Confidentiality:

The confidentiality of the information you provide will be ensured as much as possible. Data collected will be kept secured in the encrypted device accessible by Principal investigator. Your consent form and your information will be kept in a research record created for you and they will be only accessible to the researchers.

Outputs

The results of this research will be communicated directly to the health centers. In addition, the findings will be shared with different policymakers in Rwanda. The results will be published in scientific journals. Later, the results will be presented in a thesis that will be submitted to the University of the Witwatersrand, Johannesburg, South Africa, for assessment. As per HPCSA guidelines, we will preserve the records of the data for a minimum of two years after the study results have been published or six years if there is no publication.

Who do I contact if I want to ask more questions?

We will be happy to answer any questions you have about this study. This research has been approved by the University of the Witwatersrand Research Ethics Committee and IRB Ethical Committee Rwanda. If you have any questions about your rights as a study participant, or questions or concerns about any aspect of the study, you may contact the Chairperson of the Ethics Committee, Professor Clement Penny, telephone number 011 717 2301

or by e-mail at Clement.Penny@wits.ac.za. If you have questions about the research, you may also contact the principal investigator: Emmanuel Nzabonimana telephone: +250783880746.

Thank you for your assistance with this study

Appendix 7: Consent form

TITLE OF THE STUDY: Oral Health Status in Nyarugenge District of Rwanda: The role of mobile application in oral health education

I, _____ agree to participate in the study “Oral Health in Nyarugenge District of Rwanda: The role of mobile application in oral health education”. I have been well explained about the risks and benefits of participating in this study; I am aware that participation in the study is voluntary, and I am aware that I will not be paid for the participation. In addition, all information provided will be treated with confidence, and that my anonymity will be maintained. I am aware that the results of this study may be published, but I will not be identified as an individual. I reserve the right to withdraw from the study at any time if I so wish without any penalty.

Signature of participant

Date /...../....

Signature of the principal investigator

.....

Emmanuel Nzabonimana

E-Mail: enzabonimana@cartafrica.org

Tel: +250 783880746

Kigali, Rwanda.

Appendix 8 Consent form for audiotaping

Title of the study: Oral Health Status in Nyarugenge District of Rwanda: The role of mobile application in oral health education

I, _____ agree to participate in the study “: Oral Health in Nyarugenge District of Rwanda: The role of mobile application in oral health education”. I accept that the interview will be recorded using an electronic recording device. I have been well explained about the risks and benefits of participating in this study; I am aware that participation in the study is voluntary, and I am aware that I will not be paid for the participation. In addition, all information provided will be treated with confidence, and that my anonymity will be maintained. I am aware that the results of this study may be published, but I will not be identified as an individual. I reserve the right to withdraw from the study at any time if I so wish without any penalty.

Signature of participant

Date / /

Signature of the principal investigator

.....

Emmanuel Nzabonimana

E-Mail: enzabonimana@cartafrica.org

Tel: +250 783880746

Kigali, Rwanda.

Appendix 9 : Covid 19 guideline protocol Rwanda by RBC

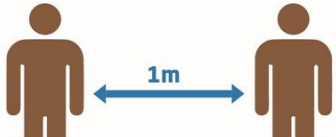
DORE UKO WAKWIRINDA KORONAVIRUSI



Karaba intoki buri gihe ukoresheje amazi meza n'isabune cyangwa alukoro yagenewe gusukura intoki



Ambara agapfukamunwa neza uhaye ku zuru, ugeze muni y'akananwa



Siga intera ya metero imwe hagati yawe n'undi muntu



Ishyura ukoresheje Telefone cyangwa irindi koranabuhanga

IBIMENYETSO MPURUZA BYA KORONAVIRUSI



Guhinda umuriro



Gukorora



Guhumeka nabi

Uramutse ufite kimwe muri ibi bimenyetso, ihutire guhamagara inomero itishyurwa **114** cyangwa wohereze ubutumwa kuri whatsapp **+250788202080**

 callcenter@rbc.gov.rw





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Repubulika y'u Rwanda
Ministeri y'Ubuzima



rbc Rwanda
Biomedical
Centre
Healthy People, Wealthy Nation



World Health
Organization



unicef
kuri buri mwana

Source(78, 79)

Appendix 10 KAP study data collection form

The data collection tool was adapted from previous studies that assess oral health knowledge, attitude, and practices ([25](#), [74](#), [75](#)).

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF THE PATIENTS

1. **Participant Unique number:**
2. **Age in years:**
3. **Gender**
 - 1: Male.....
 - 2: Female.....
 - 3: Other.....
4. **Marital status**
 - 1: Single.....
 - 2: Married.....
 - 3: Divorced.....
 - 4: Other (I prefer not to say)
5. **Do you have a smartphone?**
 - 1: Yes.....
 - 2: No.....
6. **If yes, what is the type of smartphone do you have?**
 - 1: Android
 - 2: Apple
7. **Are you able to read and understand any of the following language?**
 - 1: English
 - 2: French
 - 3: Both English and French
 - 4: Only Kinyarwanda
8. **I want to give you a mobile that give oral health education, if you accept please give me your phone number so that I will be able to communicate with you after 4 weeks to ask you about the mobile that I gave you.**
9. **What type of Health Insurance do you have?**
 - 1: Public health insurance

2: Private

10. What is your level of education?

1: Primary

2: Secondary

3: University

4: No education/or other ...

SECTION B: ORAL HEALTH KNOWLEDGE

Answer the following statements by choosing “YES” or “NO” or “DO NOT KNOW”:-		Yes	No	Do not know
According to my understanding,				
1.	To prevent tooth decay, I have to brush, especially on the crown covers of my teeth.			
2.	Tooth-brushing should be done in the morning after waking up and before bed at night every day.			
3.	Dental plaque can cause gum diseases and tooth decay.			
4.	Gum bleeding is a sign of gum disease.			
5.	In order to prevent gum inflammation, you also have to clean between your teeth.			
6.	The hard deposit on your teeth can remove itself with tooth-brushing alone.			
7.	Bad breath can be caused by gum disease.			
8.	When my gum does not bleed while brushing my teeth, there is nothing wrong with my gum.			
9.	I know the cause of tooth decay.			
10.	A regular dental checkup is necessary.			

SECTION C: ORAL HEALTH ATTITUDE Answer the following statements by choosing between 1 to 5 :- I think...		Strongly disagree (1), Disagree (2), Do not know (3), Agree (4), Strongly agree (5)				
		1	2	3	4	5
1.	The hardness of bristles of the tooth-brush has an effect on teeth and gums.					
2.	Well cleaning of teeth can be done without using toothpaste.					
3.	Dentists should be visited regularly, even without having an oral problem.					
4.	I must perform oral self-care regularly to identify any abnormality in my mouth, such as a hard deposit on my teeth.					
5.	I cannot remove the hard deposit on my teeth with tooth-brushing alone.					
6.	Waiting until I have toothache before visiting dentists can lead to tooth extraction.					
7.	Caring for my mouth is as important as caring for other parts of the body.					

SECTION D: ORAL HEALTH PRACTICES- Choose one answer in each of the following questions:

1. Which method do you use to clean your teeth?

- A. Tooth-brush and paste
- B. Only toothpaste
- C. Only tooth-brush
- D. Finger
- E. None

2. How often do you brush your teeth?

- A. No brushing
- B. Sometimes
- C. Brushing once a day in the morning

- D. Brushing once a day at night
- E. Brushing twice a day

3. When do you brush your teeth?

- A. Morning before breakfast
- B. Morning after breakfast
- C. Noon after lunch
- D. Night before going to bed
- E. Morning after breakfast and night before going to bed

4. How long do you brush your teeth?

- A. Less than 1 min
- B. One min
- C. Two min
- D. More than 2 min
- E. Do not know

5. Which type of toothpaste do you use?

- A. Non-fluoridated
- B. Fluoridated
- C. Do not know
- D. Do not use toothpaste
- E. I use something else ... give example.....

6. Which type of tooth-brush do you use?

- A. Hard bristle
- B. Soft bristle
- C. Medium bristle
- D. Do not know
- E. Do not use tooth-brush

7. How often do you replace your tooth-brush?

- A. One month
- B. Three months

- C. Six months
- D. When the bristles are worn out
- E. I do not use a tooth-brush

8. How do you use your tooth-brush when brushing your teeth?

- A. Vertical strokes
- B. Horizontal strokes
- C. Circular motion
- D. Combination of the above
- E. I do not use a tooth-brush

9. How often do you use dental floss to clean your teeth?

- A. Once a day
- B. Twice a day
- C. Sometimes
- D. Once a week
- E. Never

10. How often do you visit dental services?

- A. Every 6 months
- B. Every 12 months
- C. Occasionally
- D. Only when I have dental pain
- E. Never visited

11. What are the reason for visiting dental services?

- A. Dental pain
- B. Tooth cleaning
- C. Oral checkups and advice
- D. Gum problems
- E. Rotten tooth

12. Do you have any of the following regarding dental visits?

- A. Fear of drill

- B. Fear of needle
- C. High cost
- D. Lack of time
- E. Distance too far

Appendix 11: Oral health services data collections tools

The questionnaire was adapted from a study conducted by Josephin et al., (2018) in Zambia(47).

QUESTIONNAIRE FOR QUANTITATIVE STUDY

FACILITY ASSESSMENT CHECKLIST FOR ORAL HYGIENE SERVICES

FACILITY Unique name and number:

1. BIH (1)
2. COH (3)
3. KBH (5)
4. KYH (6)
5. NYH (9)
6. MUDH (11)
7. CKH (12)

In order to assess the availability and adequacy of oral hygiene services in the dental clinic. The item is divided into three dimensions

SECTION A: Dental equipment and instruments.

SECTION B: Essential dental material for polishing.

SECTION C: Oral hygiene instructions to patients.

Please fill in the columns; if the answer is yes, give a score of 1, and if the answer is no, give a score of 0.

Yes =1, No=0

SECTION A – Dental Equipment and Instruments

1. Essential equipment

Serial No	Essential equipment	Availability	Functionality	Adequacy
1	Dental chair			
2	Dental light			
3	Dental stool			
4	Dental compressor			
5	Suction lines			
6	Benchtop sterilizing unit			

2. Diagnostic dental instruments

Serial No	Essential equipments	Availability	Adequacy
1	Dental tray		
2	Mouth Mirrors		
3	Explorers		
4	Periodontal probes		

3. Instruments for scaling and polishing

Serial No	Essential equipments	Availability	Functionality	Adequacy
1	Ultrasonic scaler unit			
2	Ultrasonic tips			
3	Manual scaling set			
4	Suction tips			
	Instruments for polishing			
5	Prophylaxis handpiece			
6	Prophylaxis angle			
7	Prophylaxis cup/brush			

4. Personal protective equipment

Serial No	Personal protective equipment	Availability	Adequacy
1	Surgical gloves		
2	Mouth mask		
3	Protective eyewear		

SECTION B:

Essential dental material for polishing

Serial No	Essential dental material for polishing	Availability	Adequacy
1	Prophylaxis paste		

SECTION C:

Oral hygiene instrument for the patients' education

Serial No	Materials for oral hygiene instructions	Availability
1	Model and tooth-brush	
2	Dental floss or interdental tooth cleaning	
3	Specific mobile application for oral health education	

Appendix 12: In-depth interview guide on challenges faced by oral health professionals in rendering oral health services to the community of Nyarugenge District.

The questionnaire was adapted from a study conducted by Josephin et al., (2018) in Zambia([47](#)).

Participant Unique Number:

Place of interview:

Time of interview:

This in-depth interview explores the various challenges that might be facing dental professionals in providing oral hygiene services to the community.

Probe=P

Thank you for accepting that we have this conversation. This research is one of the requirements for my fulfilment of a **Doctor of Philosophy (PhD) in the School of Oral Health Sciences, University of the Witwatersrand, Johannesburg**. I want to request you to participate in the interview that addresses the challenges you might face as dental professionals in offering oral hygiene services to the community. This interview would also like to assess the impact of a mobile App in oral health education. We would like to request your permission to record this interview so that we don't lose any information you will give us. We guarantee that your voice or your speech will never be shared with anyone or stored online; it will be kept confidential and used for the sole purpose of addressing the challenges. There is no wrong answer, all answers are important. So, feel free and tell us everything as it is. Do you agree with the voice recording?

Q 1: How is your work currently? We would like that you tell us how it is for you. If you enjoy it, if it is very exhausting, if sometimes you have to increase your speed in each procedure in order to finish seeing all the patients, or if there are some challenges. Feel really free and tell us how it is.

P1: Did you expect to treat so many patients in a day?

Q2: Tell us about giving oral health education to every patient that comes to you (Is it possible? If you think that it is not possible or if that it is very challenging, could you explain the reasons?)

P1: In case you manage to give oral health education to your patients, what are the main components? (brushing technique demonstration, demonstration to every patient the proper way to use a dental floss, dietary instruction...) Tell us.

P2: Which challenges have you experienced while providing oral health education to your patients?

Q3: Tell us now about your ability to provide scaling and polishing treatment to all the patients who need it (If there is a lot of need, how many patients need that treatment, if you face some barriers in providing scaling and polishing treatment).

Q4: What about the sterilization of instruments for scaling and polishing? (is there any challenge about that??

P: Has there been instances where you could not provide treatment due to lack of sterilized instruments? (What had happened)?

Q5: What do you do after completing the treatment? (Do you get time to give oral hygiene instructions to patients after a procedure?)

Q6: When considering the quality of treatment that you are offering to your patients, how do you feel about it? (Are you satisfied with the quality of treatment offered to them?)

Q7: What happens when one of the equipment in the dental clinic stops working or needs repair?

P1: If the dental chair, ultrasonic scaler, or sterilizer needs repairing (Is it done immediately? Is it neglected? Do they take a long time before repairing it?) Tell us about it.

Q8: How about dental materials like polishing paste? What happens when they are finished? (is it replaced immediately or?

Q9: Tell us about your safety while providing treatment. (Do you feel that you are at risk of being contaminated while providing treatment? What about personal protective equipment like face masks, gloves, protective eyes wear, etc., are there readily available?)

Q10: In your opinion, what would decrease your workload?

P1: More professional staff, more dental chairs, more instruments, etc.

P2: If there is a mobile application in phones that offers oral health education to patients, what would be an added advantage for your work? (Do you think that a mobile application

in phones that offers oral health education to patients would help you reducing the time you spent for educating your patients?

Q11: What are your suggestions to improve oral hygiene treatment facilities in the dental clinic?
(So that they became more user friendly for you?)

.....

Q12: What suggestions can you make so that your work becomes much easier?

P: What about equipment, instrument, and other dental materials? Are they available? Are they adequate? Tell us about that

XX

Appendix 13: Feasibility and acceptability Survey Questionnaire

Part A. Demographic variables

1. Gender: ☐ Male; ☐ Female
2. Age, in years: ☐ < 35; ☐ 35-44; ☐ 45-54; ☐ 55-64; ☐ 65 or older
3. Education level: ☐ Less than high school; ☐ High school; ☐ College or university up to bachelor;
☐ College or university up to master or PhD

PART B: Habitual variables on oral hygiene	Yes	No
1. I brush my teeth when I wake up and before going to bed every day.		
2. I clean teeth (brush or rinse with water) after meals.		
3. I use floss to clean my teeth every day.		
4. I use an interdental brush to clean my teeth every day.		
5. I think regular oral cleaning (brushing and interdental cleaning) is important.		
6. I think I have good oral health.		

PART C: Oral health app acceptability assessment		Strongly disagree (1), Disagree (2), Do not know (3), Agree (4), Strongly agree (5)				
Answer the following statements by choosing between 1 to 5 :-		1	2	3	4	5
1.	I think that I would like to use this App frequently.					
2.	I found the App unnecessarily complex.					
3.	I thought the App was easy to use.					
4.	I think that I would need the support of a technical person to be able to use this App.					
5.	I found the various functions in this App were well integrated.					
6.	I thought there was too much inconsistency in this App.					
7.	I would imagine that most people would learn to use this App very quickly.					
8.	I found the App very cumbersome to use.					

9.	I felt very confident using the App.					
10.	I needed to learn a lot of things before I could get going with this App.					

SECTION D: Oral health App preference assessment Answer the following statements by choosing between 1 to 5 :-		 Strongly disagree (1), Disagree (2), Do not know (3), Agree (4), Strongly agree (5)				
		1	2	3	4	5
1.	I like the oral care video, which makes me learn more about oral cleaning.					
2.	I like the App pointing out the focal areas in my mouth that require extra care.					
3.	I like the App showing the focal areas that require extra cleaning effort in the dental chart.					
4.	I like the App reminding me to use dental floss and an interdental brush to clean my teeth.					
5.	I like the App user manual, it makes the App easy-to-use.					
6.	I like the App rewarding with applause when achieving a tooth-brushing session.					
7.	I like the App providing important information about oral health.					
8.	I like the App allowing me to set reminders for tooth brushing.					
9	I like the App reminding me to brush my teeth according to the time that is set.					
10	I like the App reminding me to clean my teeth at least twice a day.					
11	I like the App showing the progress of tooth brushing with an arrow, which directs me to brush my teeth in the same order.					

12	I like the App making the red indicators disappear when I have finished brushing the focal areas.					
13	I like the background music played in the App during the tooth brushing session.					
14	The App was useful.					

Source ([77](#))

Research



Oral health knowledge, attitude and oral hygiene practices among adults in Rwanda

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Oral health knowledge, attitude and oral hygiene practices among adults in Rwanda

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Abstract

Introduction: oral diseases (OD), common dental caries and periodontitis are a major public health problem. Poor oral hygiene has been associated with OD, causing tooth loss, which leads to disability and compromised patients' oral health. In Rwanda, OD is among the leading causes of morbidity at the health center level. Therefore, the purpose of this study was to assess the knowledge, attitude, and oral health practices among adult participants in Rwanda. Methods: a descriptive cross-sectional study was done among participants attending public health facilities in Nyarugenge District, Rwanda. Participants were interviewed using a structured questionnaire. The data were analyzed using frequency distribution, percentage distribution, and bivariate and multivariate logistic regression at a 5% significant level.

Results: among 426 participants who were interviewed, 39.44% (n=168) were 18-27 years old and the majority, 61.5% (n=262) were female. Poor oral health knowledge was found in 42% (n=179) of the participants, whilst 12.44% (n=53) showed poor oral health attitudes, and 67.37% (n=287) were found to have poor oral health practice. Participants with a high school level of education were more likely to have better oral health knowledge and the results were statistically significant aOR: 1.79, 95% CI 1.14; 2.82; p = 0.011 Conclusion: the findings of our study showed that almost half of the participants had poor oral health knowledge. Oral health attitude and oral hygiene practices were also lacking. There is a need to enhance oral health education in this community to improve their oral health knowledge, attitudes, and practices.

Introduction

Oral diseases (OD), commonly tooth decay and periodontal disease, are a major public health problem with 3.58 billion people reported to have tooth decay, according to the Global Burden of Disease Report conducted in 2015 [1]. Periodontal diseases are prevalent in developed and developing countries and affect about 20-50% of the global population [2]. Some studies have found a strong association between poor oral hygiene and common dental diseases such as dental caries and periodontal diseases [3,4]. Globally, the burden of oral disease is high among older people and has a negative effect on their quality of life [5]. Poor oral hygiene causes tooth loss, which leads to disability and compromised patients' oral health [6]. In Africa, OD is a significant public health problem [7]. The prevalence of dental caries has increased in many African countries and may further increase due to increased sugar consumption and inadequate exposure to fluorides [7]. The prevalence of gingival inflammation is high in all age groups in several African countries [8]. In a study from Sudan, about 64.5% of participants considered poor tooth brushing habits to cause gingivitis and

less than 20% of adolescents visit dentists regularly for a dental check-up [9]. In Tanzania, a study found that 44.8% of the participants had fair to poor oral hygiene status [10]. A Ugandan study found that 56% of participants had not visited oral health services in the last two years, and those who did were due to pain [11].

In Rwanda, OD is among the leading cause of morbidity at the health center level, with poor oral hygiene, tooth decay, and periodontal disease, have been reported [12-14]. The Rwanda National Oral Health Survey in 2018 found that the oral health status of the population was poor, with 70% of individuals not utilizing oral health services. Adults aged 20 years and above from Rwanda have been reported to present with oral debris, and dental calculus [14]. Studies have associated low health literacy with greater use of emergency care and poor preventive health-seeking behavior for oral health services [15,16]. A correlation between limited oral health knowledge and poor oral health behavior has been reported [17], however, there is a scarcity of information on oral health awareness levels in Rwanda. Therefore, this study evaluated knowledge, attitude, and oral hygiene practices among adults in Rwanda. It is part of a large doctoral study entitled "Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Application in Oral Health Education."

Methods

Study design and setting: a descriptive cross-sectional study was conducted among participants attending public health facilities in Nyarugenge District, Rwanda. Rwanda stands as one of the 56 countries in the African continent. Rwanda is divided into four provinces, plus Kigali City, the capital city. The four provinces have 27 Districts, while Kigali City has three districts (Gasabo, Kicukiro, and Nyarugenge) based on Government data [18,19]. The study was conducted in July 2022 in Nyarugenge District, Kigali City, Rwanda.

Study population: adult patients aged 18 years and above attending health services in

Nyarugenge District. Participant who voluntarily agreed and signed informed consent to participate were included in the study. Patients who were hospitalised and mentally challenged were excluded from the study. The seven urban health facilities services in Nyarugenge District were randomly sampled to obtain three health centres. The participants were selected conveniently from the three health centres. The sample size was calculated based on the estimated oral health knowledge prevalence of 50%, with 95% confidence level and 5% level of precision to be 42 [20].

Data collection: data were collected by principal investigator (EN) and four research assistants who have dental background with adequate experience in collecting quantitative data. The participants were recruited conveniently and those who consent were interviewed in Kinyarwanda local language using a structured questionnaire which was adapted from previous reported studies [21-23]. The questionnaire elicited the demographic characteristics, oral health knowledge, oral health attitude, and oral hygiene practices of the participants.

Definition

Outcome variable: oral health knowledge, oral health attitude, and oral hygiene practices.

Exposure variable: demographic characteristics (age, gender, marital status, owning smartphone and level of education).

Statistical analysis: the Stata software version 16 was used for analysis (StataCorp, College Station, Tx). Descriptive statistics frequency and percentage distribution were used to analyze demographic characteristics, oral health knowledge, oral health attitude, and oral hygiene practice. Bivariate and logistic regression was done to assess factors associated with oral health knowledge, oral health attitude, and oral hygiene practices. The oral health knowledge questions were analyzed by assigning the most correct

answer a score of "1", and wrong answers and don't know a score of "0". The nine statements on knowledge were summed up to a total score of 9, equivalent to 100%. A score of less than 60% was classified as 'poor oral health knowledge' and a score of 60% and above indicated 'good oral health knowledge'. The oral health attitude questions were analyzed by allocating the positive attitude a score of "1" and the negative attitude a score of "0" while neutral responses were not allocated any score and not used in computing the total attitude score. The attitude responses were summed up to a total score of 7 indicating 100% good attitude. The attitude score of less than 60% indicated a poor oral health attitude, and the score of 60% and above showed a good oral health attitude. In addition, the responses of attitudes "strongly disagree" and "disagree" were combined to "disagree" and "strongly agree" and "agree" were combined and became "agree", and neutral responses were reported as it is in the frequency tables. Oral hygiene practice questions were analyzed by allocating the most correct answer a score of "1", and the wrong answer a score of "0". The response score was summed up to a total score of 8, indicating 100% good oral hygiene practices. A score of less than 60% were categorized as 'poor oral hygiene practices' and scores of 60% and above indicated 'good oral hygiene practices'.

Ethics consideration: the Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand, Johannesburg provided ethics approval (M220213) to conduct the research. Permission was also obtained from the relevant healthcare authorities, Rwanda IRB ethical committee (No234/CMHS IRB/2022), and the National Health Research Committee (No NHRC/2022/PROT/26). Informed consent was signed by all participants.

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Results

Demographic characteristics of the participants: a total of 426 respondents participated in the study, with majority in the 18-27 years old age category (39.44%; n=168). The median age was 30, interquartile range (IQR) at 25 - 39. The majority of the participants, (61.5%; n=262) were female (Table 1).

Oral health knowledge, attitude and practice: poor oral health knowledge was found in 42.02% (n=179) of the participants. Oral health practices, 67.37%(n=287) and oral health attitude 12.44%(n=53) were also poor.

Frequency distribution of oral health knowledge among the respondents: most of the respondent knew the importance of tooth cleaning, even though some had poor oral knowledge of the cause of gingival disease. The majority of the respondents 82.16% (n=350) knew the importance of cleaning between teeth in order to prevent gum inflammation. Most of the participants knew the importance of regular dental check 74.88% (n=319), while 25.12% (n=107) of the respondents did not know. Regarding tooth brushing 39.19% (n=397) of the respondents knew that tooth brushing should be done in the morning and at night daily (Table 2).

Frequency distribution on oral health attitude among the respondents: according to the respondents' attitude towards oral health, 56.19% (n=227) do not believe that teeth can be cleaned

effectively without using toothpaste, while 43.81% (n=177) agree with this statement. Believe on dentists should be visited regularly, even without having an oral problem 23.66% (n=97) disagree, 76.34% (n=313) agree. 3.33% (n=14) disagree and 96.67% (n=406) agree regarding oral health attitude on performing oral self-care regularly to identify any abnormality in my mouth, such as a hard deposit on my teeth (Table 2).

Oral health practices among the respondents: most respondents, 64.1%(n=273) brushed their teeth twice a day, while 35.9% brushed them once daily. The soft bristle toothbrush was used by 35.9%(n=153) of respondents, while 21.1% (n=90) used a hard bristle toothbrush. 32.2% (n=137) (32.2%) participants never visited dental services, whilst 51.6%(n=220) only visited dental services due to pain, and 3.1% (n=13) 13 respondents (3.1%) visited dental services every six months. Most of the respondents 92.7% (n=395) had never used dental floss to clean their teeth, and only 4(0.9%) of the respondents used it twice daily, 9(2.11%) used it once a day and 15 (3.52%) use dental floss sometimes and 0.7% (n=3) use once a week (Table 3).

Frequency distribution of the reason for visiting dental services: the majority of the respondents n=230 (79.58%) among 289 who visited dental services in the past, had visited dental services due to pain, while 12 (4.15%) respondents visited dental services for teeth cleaning, 16 (5.54) respondents visited dental services for oral check-ups and advice, 8 (2.77%) visited dental services for gum problems and 23 (7.96%) participants sought dental services due to gum problems.

The association between oral health knowledge, oral health attitude, oral health practices, and demographic characteristics: oral health knowledge was found to be significantly associated with oral health practices (P-value=0.017), oral health attitude (P-value=0.000) and level of education (P-value=0.006). Owning a smartphone was found to be significantly

associated with oral health knowledge (P-value=0.011), oral health attitude (P-value=0.049) and oral health practice (P-value=0.011) (Table 4).

Logistic regression for KAP and demographic characteristics of the respondents: the variables found being significant in the univariate analysis concerning oral health knowledge were marital status, smartphone ownership, and level of education. Oral health practices showed significant associations with smartphone ownership and level of education in the univariate analysis. In the multivariate analysis, individuals with a high school education were more likely to possess better oral health knowledge aOR=1.79, 95% CI 1.14; 2.82 and p-value 0.011 (Table 5).

Discussion

Our study is among the first to report data on oral health knowledge, attitudes, and oral hygiene practices of adult participants in Nyarugenge, Rwanda. The study revealed that among Nyarugenge adults, more than 40% exhibited knowledge deficits. The oral health attitudes and oral hygiene practices were also found to be poor. The findings showed that most of the participants were young adults between 18 and 37 years old. A similar age group has been reported in India and Nigeria where the participants evaluated dental needs [24,25]. The current results showed that most of the participants were women. Previous studies have reported a similar gender predominance, citing that women were more proactive in seeking dental care [26]. Similar gender differences were reported in Saudi Arabia and India where it was found that women acted more positively than men on oral health [27,28].

Our results showed that almost half of the participants had poor oral health knowledge. Our sample knowledge (58.0%) was lower compared to 62.2% reported in Nigeria, but it was similar to that reported in Spain with oral health knowledge of 58.5% [29,30]. Although in our study participants knew that they must brush their teeth

to prevent tooth decay (84.27%) and that to prevent gum inflammation, it is also necessary to clean between teeth (82.16%), most of them did not feel that a regular dental visit was necessary. Our study participants' knowledge of dental and gum care was lower than in the results reported in Cyprus at 97.3% and 96% respectively [31] and Romanians at 95.3 and 88.3% [32]. The knowledge of the participants in our study was strongly associated with the ownership of a smartphone (P=0.011), secondary education (P=0.006), good oral hygiene practices (P=0.017), and good oral health attitudes (P=0.000). A study conducted in Iran found an association between oral health knowledge and financial status, which can be reflected in our study as the ownership of a smartphone [33]. In addition, a similar association was reported between oral health knowledge and a higher level of education among adult populations in Spain [30]. More educated people are more likely to use reading, social media, news, and the internet to learn more. Bastani *et al.* found that smartphone-delivered oral health information enhanced knowledge [34]. The association between oral health knowledge and attitude was consistent with what was found in China [35] but contrasting results were found in the South Indian population [36].

These differences might be due to different geographic location, sociodemographics of the participants, and access to oral health care. The knowledge of study participants also reflected on their attitude, where 69.25% demonstrated a good attitude. This overall attitude was better compared to the South Indian, Saudi Arabian, and Nigerian populations where the attitude levels were 33.3%, 48.3%, and 44.5% respectively [36,37]. The differences could be attributed to the different settings where the studies were conducted. In our study, only 76.34% of the participants agreed that dentists should be visited regularly, even without having an oral problem. The participants agreed that waiting until they have a toothache before visiting the dentist can lead to tooth extraction. Our findings are almost similar to the study with Libyan's parents,

who agreed that regular dental check-ups are important for the prevention of dental problems at 79.5% [38]. However, the attitude of Romanian dental patients was better compared to our study participants because 88.3% of them agreed that regular dental check-ups can prevent dental problems [32]. Our study findings showed that the participants' attitudes were associated with oral health knowledge ($P=0.002$). A similar association between attitude and oral health knowledge was also found among Iranian patients [18] and Brazilian patients [39]. According to Rodrigues *et al.*, a patient's attitude is a key construct for causing them to adopt a certain behavior and maintain that behavior [39]. The participants' attitudes in our study were also associated with ownership of a smartphone ($P=0.049$). The relationship between the ownership of the smartphone and the level of attitude could be that smartphone users tend to obtain more information online, which may improve their attitude.

The knowledge and oral health attitudes levels of our study participants did not translate to improve their oral hygiene practices. Only a third of our study participants displayed good oral hygiene practices, in contrast to the Libyan study, where 78.7% of parents displayed good oral hygiene practices [38]. Similarly, good practice findings have been reported in the literature [32,33,35] except in Brazil where low oral health literacy was associated with poor oral hygiene practices [33,40]. Approximately 64.08% of our study participants brushed their teeth twice a day, compared to the Chinese dental patients who reported that 77.4% brushed their teeth twice a day [41].

Furthermore, 51.64% of our study participants responded that they should visit dentists only when they experience pain, as compared to 55% of the Saudi Arabian participants [42]. The results of our study found poorer oral hygiene practices in contrast to the Indian study where 82.0% of the participants went for routine dental check-up and 25.8% expressed that the reason for their last

dental visit was only consultation and advice [27,38]. Dental flossing was not popular among our study participants because 92.7% reported never using a dental floss. Similarly, dental flossing was low in Romania at 27.9% [32]. Oral hygiene practices in our study were found to be only associated with oral health knowledge. The result of our study differed from what was found in Brazil, where level of education was associated with oral health practices [40].

One of our study's limitations is the use of a cross-sectional design, which cannot establish causality. However, we addressed this limitation by conducting a regression analysis that adjusted for confounding factors likely to influence the outcomes. Additionally, our study's sample bias arose from recruiting participants solely from government facilities, limiting the generalizability of results to those using private facilities. Moreover, because the data was collected from one district with a limited sample size, this study cannot be generalized to the entire country.

Conclusion

Almost half of the adults in Nyarugenge district had poor oral health knowledge, one-third of them had poor oral hygiene practices despite showing good oral health attitudes. The discordance requires that oral health education and oral health attitudes be improved. The association between smartphone ownership and oral health knowledge was identified among the participants. This suggests an opportunity to utilize smartphones as educational tools for oral health alongside traditional methods to enhance knowledge and promote better oral hygiene practices.

What is known about this topic

- Optimal oral health is the gateway to general health of all individuals;
- Oral health knowledge may influence oral hygiene attitudes and practices;

- *Good oral hygiene practices depend on several factors including individual level, community level, organisational level as well as oral health policies.*

What this study adds

- *This is one of the first studies to report on the oral health status, knowledge, attitude, and practices of adults in Nyarugenge, Rwanda;*
- *The findings of this study will be useful in planning the oral health educational in the community;*
- *This study shows the relationship between KAP and demographic characteristics.*

Competing interests

The authors declare no competing interests.

Authors' contributions

Conception and study design: Emmanuel Nzabonimana, Phumzile Hlongwa, and Yolanda Malele-Kolisa. Data collection: Emmanuel Nzabonimana. Data analysis and interpretation: Emmanuel Nzabonimana, Phumzile Hlongwa, and Yolanda Malele-Kolisa. Manuscript drafting: Emmanuel Nzabonimana. Manuscript revision: Emmanuel Nzabonimana, Phumzile Hlongwa, and Yolanda Malele-Kolisa. Guarantor of the study: Emmanuel Nzabonimana. All authors approved final version of the manuscript.

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Tables

Table 1: demographic characteristics of the participants

Table 2: frequency distribution of oral health knowledge and oral health attitude

Table 3: oral health practice

Table 4: association between KAP and demographic characteristics

Table 5: logistic regression for oral health knowledge, oral health attitude, oral health practice and demographic characteristics

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Table 1: demographic characteristics of the participants		
Demographic (n=426)	Frequency	Percentage
Age		
18-27 years	168	39.44%
28-37 years	129	30.28%
38-47 years	73	17.14%
48-57 years	34	7.98%
58-88 years	22	5.16%
Gender		
Male	164	38.5%
Female	262	61.5%
Marital status		
Single	136	31.9%
Married	271	63.6%
Divorced	12	2.8%
Other	7	1.6%
Participant own smartphone		
Yes	151	35.4%
No	275	64.6%
Level of education		
Primary	189	44.6%
Secondary	178	42%
University	31	7.3%
No education	26	6.1%

Table 2: frequency distribution of oral health knowledge and oral health attitude			
Oral health knowledge n=426	Yes (n %)	No	Don't know
To prevent tooth decay, I have to brush, especially on the crown covers of my teeth	359 (84.27%)	36 (8.45%)	31 (7.28%)
Toothbrushing should be done in the morning after waking up and at night before going to bed every day	397 (93.19 %)	22 (5.16 %)	7 (1.64%)
Dental plaque can cause gum diseases and tooth decay	390 (91.55%)	12 (2.82%)	24 (5.63%)
Gum bleeding is a sign of gum disease	376 (88.26%)	26 (6.10%)	24 (5.63%)
To prevent gum inflammation, you also have to clean between your teeth	350 (82.16 %)	21 (4.93%)	55 (12.91%)
The hard deposit on your teeth can remove itself with toothbrushing alone	213 (50.00%)	164 (38.50%)	49 (11.50%)
Bad breath can be caused by gum disease	241 (56.57%)	97 (22.77%)	88(20.66%)
When my gum does not bleed while brushing my teeth, there is nothing wrong with my gum	324 (76.06%)	60 (14.08%)	42(9.86%)
A regular dental check-up is necessary	319 (74.88%)	89 (20.89%)	18 (4.23%)
Oral health attitude n=426	Disagree	Agree	Neutral
Do you think the hardness of the bristles of the toothbrush affects teeth and gums?	29 (7.04%)	383 (92.96%)	14 (3.29%)
Do you think well-cleaning of teeth can be done without using toothpaste?	227 (56.19)	177 (43.81%)	22 (5.16%)
Do you think dentists should be visited regularly, even without having an oral problem?	97 (23.66%)	313 (76.34%)	16 (3.76)
Do you think you must perform oral self-care regularly to identify any abnormality in your mouth, such as a hard deposit on your teeth?	14 (3.33 %)	406 (96.67%)	6 (1.41%)
Do you think you cannot remove the hard deposit on your teeth with toothbrushing alone?	154 (38.79%)	243 (61.21%)	29 (6.81%)
Do you think waiting until you have toothache before visiting dentists can lead to tooth extraction?	93 (22.96%)	312 (77.04%)	21 (4.93%)
I think caring for my mouth is as important as caring for other parts of the body	6 (1.44%)	412 (98.56%)	8 (1.88%)

Table 3: oral health practice			
Oral health practice		Frequency	Percentage
The method used to clean	Toothbrush and paste	422	99.06
	Finger	2	0.47
	None	2	0.47
When do you brush your teeth	Morning before breakfast	107	25.12
	Morning after breakfast	37	8.69
	Noon after lunch	5	1.17
	Night before going to bed	4	0.94
	Morning after breakfast and night before going to bed	273	64.08
the duration of brushing teeth	Less than 1 min	27	6.34
	One min	122	28.64
	Two min	88	20.66
	More than 2 min	176	41.31
	Do not know	13	3.05
Type of toothbrush used	Hard bristle	90	21.13
	Soft bristle	153	35.92
	Medium bristle	156	36.62
	Do not know	21	4.93
	Do not use toothbrush	6	1.41
The duration of replacing the toothbrush	One month	121	28.40
	Three months	141	33.10
	Six months	20	4.69
	When the bristles are worn out	140	32.86
	I do not use a toothbrush	4	0.94
The type of motion used during brushing	Vertical strokes	31	7.28
	Horizontal strokes	276	64.79
	Circular motion	4	0.94
	Combination of the above	110	25.82
	I do not use a toothbrush	5	1.17
How often do you visit dental services?	Every 6 months	13	3.05
	Every 12 months	56	13.15
	Only when I have dental pain	220	51.64
	Never visited	137	32.16
Use of dental floss	Once a day	9	2.11
	Twice a day	4	0.94
	Sometimes	15	3.52
	Once a week	3	0.7
	Never	395	92.72
*P-value <0.05			

Table 4: association between KAP and demographic characteristics

	Poor oral knowledge n (%)	Good oral knowledge n (%)	P value	Poor oral attitude n (%)	Good oral attitude n (%)	P value	Poor oral practice n (%)	Good oral practice n (%)	P value
Age group									
18-27 years	63 (35.2)	105 (42.51)	0.468	18 (33.96)	119 (40.34)	0.862	104 (36.24)	64 (46.04)	0.344
28-37 years	60 (33.52)	69 (27.94)		18 (33.96)	91 (30.85)		89 (31.01)	40 (28.78)	
38-47 years	29 (16.2)	44 (17.81)		10 (18.87)	50 (16.96)		53 (18.47)	20 (14.39)	
48-57 years	16 (8.94)	18 (7.29)		5 (9.43)	20 (6.78)		24 (8.36)	10 (7.19)	
58-88 years	11 (6.15)	11 (4.5)		2 (3.77)	15 (5.08)		17 (5.92)	5 (3.6)	
Total	179 (100)	247 (100)		53 (100)	295 (100)		287 (100)	139 (100)	
Gender									
Male	66 (36.31)	99 (40.08)	0.430	24 (45.28)	117 (39.66)	0.443	113 (39.37)	51 (36.69)	0.594
Female	114 (63.69)	148 (59.92)		29 (54.72)	178 (60.34)		174 (60.63)	88 (63.31)	
Total	179 (100)	247 (100)		53	295		287 (100)	139 (100)	
Own a smartphone									
Yes	51 (28.49)	100 (40.49)	0.11*	14 (26.42)	120 (40.68)	0.049*	90 (31.36)	61 (43.88)	0.011*
No	128 (71.51)	147 (59.51)		39 (73.58)	175 (59.32)		197 (68.64)	78 (56.12)	
Total	179	247 (100)		53 (100)	295 (100)		287 100	139 (100)	
Level of education									
Primary	97 54.19	92 (44.58)	0.06*	31 58.49	121 (41.30)	0.12	137 (47.74)	52 (37.96)	0.054*
Secondary	60 33.52	118 (48.16)		18 33.96	131 (44.71)		111 (38.68)	67 (48.91)	
University	11 6.15	20 (8.16)		2 3.77	26 (8.87)		18 (6.27)	13 (9.49)	
No education	11 6.15	15 (6.12)		2 3.77	15 (5.12)		21 (7.32)	5 (3.65)	
Total	179 100	245 (100)		53	293		287 (100)	137 (100)	
Oral health knowledge									
Poor knowledge	NA	NA	NA	32(60.38)	102(34.58)	0.000*	132(45.99)	47(33.81)	0.017*
Good knowledge				21(39.62)	193(65.42)		155(54.01)	92(66.19)	
Total				53(100)	295(100)		287(100)	139(100)	

*P-values ≤ 0.5 statistical significant

Table 5: logistic regression for oral health knowledge, oral health attitude, oral health practice and demographic characteristics

Factors	Oral health knowledge				Oral health attitude				Oral health practice			
	COR (95%CI)	P-value	AOR (95%CI)	P-value	COR (95%CI)	P-value	AOR (95%CI)	P-value	COR (95%CI)	P-value	AOR (95%CI)	P-value
Age	0.98 (0.97; 1.00)	0.093	1.00 (0.98; 1.02)	0.759	0.99 (0.96; 1.01)	0.456	0.996 (0.96; 1.026)	0.830	0.986 (0.96; 1.004)	0.142	0.985 (0.96; 1.007)	0.18
Gender												
Male	1.00		1.00		1		1		1		1	
Female	0.85 (0.57; 1.26)	0.430	0.95 (0.63; 1.45)	0.846	1.25 (0.69; 2.26)	0.443	1.32 (0.70; 2.48)	0.375	1.120 (0.73; 1.70)	0.594	1.073 (0.68; 1.67)	0.754
Marital status												
Single	1.00		1.00		1		1		1		1	
Married	0.61 (0.400; 0.94)	0.026*	0.62 (0.377; 1.03)	0.068	1.030 (0.54; 1.94)	0.927	1.074 (0.49; 2.34)	0.856	1.21 (0.77; 1.89)	0.396	1.52 (0.90; 2.57)	0.11
Divorced	0.51 (0.15; 1.67)	0.267	0.513 (0.15; 1.75)	0.287	0.35 (0.081; 1.57)		0.325 (0.06; 1.5)	0.162	1.2 (0.341; 4.21)	0.776	1.49 (0.40; 5.48)	0.545
Other	0.38 (0.08; 1.78)	0.222	0.40 (0.07; 2.00)	0.266	1				3.2 (0.68; 14.95)	0.139	5.064 (0.95; 26.85)	0.057
Own smartphone												
Yes	1.00		1.00		1		1		1		1	
No	0.58 (0.38; 0.88)	0.011*	0.68 (0.42; 1.09)	0.113	0.523 (0.27; 1.00)	0.052	0.665 (0.32; 1.37)	0.272	0.584 (0.38; 0.88)	0.012*	0.703 (0.43; 1.13)	0.147
Level of Education												
Primary	1.00		1.00		1		1		1		1	
Secondary	2.07 (1.35; 3.16)	0.001*	1.79 (1.14; 2.82)	0.011*	1.86 (0.99; 3.50)	0.053	1.670 (0.84; 3.31)	0.143	1.59 (1.02; 2.46)	0.039*	1.437 (0.89; 2.31)	0.135
University	1.91 (0.87; 4.22)	0.106	1.49 (0.62; 3.54)	0.365	3.33 (0.74; 14.79)		2.38 (0.48; 11.643)	0.281	1.90 (0.87; 4.15)	0.107	1.40 (0.59; 3.31)	0.443
No education	1.43 (0.62; 3.29)	0.390	1.65 (0.70; 3.88)	0.250	1.92 (0.41; 8.84)		2.44 (0.503; 11.89)	0.268	0.627 (0.22; 1.75)	0.373	0.62 (0.21; 1.79)	0.379

Note: COR: Crude odds ratio; AOR: Adjusted odds ratio; CI: Confidence interval *p-value ≤0.05 statistically significant

RESEARCH ARTICLE

Evaluation of oral health services and challenges faced by oral health practitioners working in Nyarugenge, Rwanda

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Abstract

Objective

Oral healthcare professionals encounter considerable challenges while providing services to curb the oral disease burden. The aim of this study was to explore the challenges faced by oral health practitioners providing oral health services in Nyarugenge, Rwanda and to appraise the availability and adequacy of oral hygiene equipment, instruments, and materials.

Methods

This was a cross-sectional concurrent mixed methods study. The quantitative and qualitative parts were independent during data collection and analyses and merged during the interpretation phase. All seven public health facilities and 14 dental professionals working in Nyarugenge were included in the study. Data were collected using an audit checklist and an in-depth interview guide. Descriptive statistics were used to analyze the quantitative data. The interviews were analyzed using thematic content analysis.

Results

Most of the dental health professionals were dental therapists (n = 11), women (n = 9), aged 31–40 years (n = 7), and with 11–20 years' experience as oral health practitioners (n = 6). There were five health centers and two hospitals that were audited for equipment, instruments, and materials. The audit of the facilities revealed that most facilities have dental equipment and instruments, but none have adequate preventive dental instruments and materials. Four broad themes emerged from the interviews with the oral health practitioners, namely human resources, supply chain management, patients' oral health awareness and service rendering, and strategic management and administration. The most significant challenges oral health practitioners faced included high dental practitioner/patient ratios, lack of adequate and appropriate equipment and materials, patients' lack of oral health awareness, and a lack of administrative support.

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Conclusions

Well-established community preventive interventions, such as a mobile oral health App, could reduce the patient/provider ratio by increasing population awareness of oral health and encouraging healthy behaviours. The management of the health facilities should address the human resource challenges and equipment supply chain issues.

Introduction

In their daily work, oral health professionals (OHPs) fight common oral diseases, especially periodontal disease and dental caries, which are some of the most common non-communicable diseases and are even more prevalent than cardiovascular disease [1]. However, in this fight, either through prevention or treatment, OHPs encounter many challenges. The first challenge identified by researchers is financial because dental services are expensive and considered among the most expensive healthcare treatments [2]. Consequently, dental services are difficult to afford, especially in low-income countries and even in higher-income countries among people with lower income, senior populations, and marginalized communities such as refugees, migrants, and people with disabilities [3, 4]. In the USA, more people complain of financial barriers to accessing dental care, irrespective of age, income level, and insurance type, than any other healthcare. Most treatments are not always covered by national insurance schemes, and they cover only a small range of services [5, 6]. When confronted with the problem of financing, health professionals tend to focus on clinical procedures that provide them with better remuneration instead of on risk assessment or prevention, and many prefer working in private dental clinics where they can earn better salaries [7]. This suggests that public institutions are frequented by individuals who may be unable to afford costly dental treatments [8]. Singh et al. stated that most dentists target profit compared to patients' dental problems [9]. Therefore, some dental services are not offered in public institutions due to payment challenges and the expensive nature of some dental procedures.

The provision of oral health services is further compromised by lack of infrastructure, equipment, instruments, and materials. The lack of infrastructure at primary health centers and community health centers is a major hindrance to oral health delivery in India, and this may be due to the lack of dentists that are appointed in government decision-making bodies [9]. In care homes for the elderly in Germany dental professionals have requested that a dental chair with a light should be available in every care home to facilitate dental treatment [10]. The lack of OHPs has also been reported as a problem in South Africa [7]. The lack of infrastructure leads to few working stations and few dental care providers, causing long patient waiting times, and the lack of equipment and materials impinges on the options and quality of treatments [11, 12]. In Nigeria, the lack of equipment and materials has been found to jeopardize the treatment options for patients and made OHPs to choose treatment procedures for which instruments and materials are available, such as tooth extraction [6]. The Rwanda National Strategic Plan for Oral Health 2019–2024 highlighted that in district hospitals and health centers, dental equipments, especially dental chairs, were either not available or not functioning due to lack of maintenance and lack of space for oral health services [13].

The biggest challenge experienced by OHPs when offering services has been linked to lack of human resources, which resulted to low dentist/patient ratios [14]. Different dental specialists are needed to collaborate in comprehensive oral examinations and treatment [15]. The problem of a shortage of dentists has been raised in the USA [16], and the situation is even worse in low- and middle-income countries. In Nigeria, the dentist/patient ratio was reported

to be 1:38 600, whilst in Tanzania it was 1:360 000 but in high-income countries, it was 1:2 000 [17]. Many health facilities in Nigeria have been found to have only one dental professional who does not have colleagues to consult about difficult cases [6]. OHPs' workload makes them overlook important steps in the diagnosis process, such as comprehensive oral examinations, comprehensive treatment care and oral health education. It is important to perform a comprehensive oral examination, including screening for early signs of all oral diseases, because it has been observed that most patients consult only for pain and dental emergencies [17, 18]. However, preventive measures are often neglected despite the goals of oral healthcare being a commitment to prevention [7, 9].

Apart from the financing of dental care, the availability of infrastructure and equipment, and the low dentist/patient ratio, the behavior of many patients has also been a challenge. The lack of oral health awareness among the population concerning early signs and symptoms of oral diseases, preventive measures, and regular dental check-ups resulted in late dental care-seeking behavior [6]. Even when patients have an infected tooth that can be conserved, it is challenging to convince them to comply with alternative treatments such as root canal treatments because they visit the dentist only when the pain is unbearable and insist that the tooth be removed [6, 19]. All these challenges are mostly due to oral healthcare not being included in the primary healthcare system. Oral healthcare should be integrated into primary healthcare to make it available to all people [6]. The adoption of healthy oral health preventive measures cannot take place if patients and caregivers are not given oral health education by OHPs on good oral hygiene practices such as frequent brushing, good brushing technique, interdental cleaning, regular dental check-ups, diet, and smoking cessation for the prevention of both periodontal diseases and dental caries [16].

The above-mentioned challenges can be addressed through good management. Some managerial barriers to good and equitable oral health identified in the literature are unclear goals, inadequate organization and management, poor planning, little emphasis on evaluation, and failure to plan for adequate manpower and use of auxiliaries [9]. It has been observed that dental service is often neglected during recruitment and procurement processes [6, 8, 13]. Literature demonstrates that there is international neglect and a lack of political prioritizing of oral health [16, 20]. Many public policymakers do not understand or value oral health as part of general health, making it a lower priority [9]. The affordability of dental services, the skills of OHPs, and the availability of dental equipment and materials all play important roles in the provision of comprehensive oral care, and this is the responsibility of the management of health facilities [17].

This study explored the challenges faced by OHPs in providing oral health services to the community of Nyarugenge, Rwanda. In addition, the availability and adequacy of oral hygiene equipment, instruments, and materials were also appraised. This study formed part of a larger doctoral study titled "Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Applications in Oral Health Education".

Methods

Study design

This study was a cross-sectional concurrent mixed methods study that used both qualitative and quantitative methods. The qualitative part of the study aimed to explore the challenges faced by OHPs when providing oral health services to the community of Nyarugenge District, and the quantitative part was an audit of oral health services in Nyarugenge District. The quantitative and qualitative parts were independent during data collection and analyses but were merged during the interpretation phase.

Setting

Rwanda is one of 56 countries in Africa. Rwanda is divided into four provinces and Kigali City. The four provinces each have 27 districts, and Kigali City has three districts, namely Gasabo, Kicukiro, and Nyarugenge [21, 22]. The study was conducted in seven public health facilities that offer dental services in Nyarugenge District. Five health facilities are public and two are managed conjointly by the government and the Roman Catholic Church. These health facilities service all patients, including those using community-based health insurance (CBHI).

Study population and sampling strategy

The quantitative section of the study assessed the seven public dental health facilities in Nyarugenge District, and for the qualitative section, OHPs working in the seven dental health facilities were individually interviewed. No sampling was done. All seven dental health facilities in Nyarugenge District ($n = 7$) and all OHPs working in these facilities were included in the study. Fourteen OHPs were recruited for in-depth interviews.

Data collection

The data collection tools for both the quantitative (observation checklist) and qualitative data collection (interview guide) were adapted from a study conducted in 2018 by Josephin et al. [23]. The data collection was started on 18 July 2022 and ended on 01 August 2022. The checklist items for the quantitative data collection assessed the availability, adequacy, and functionality of dental equipment. The in-depth interview guide had 12 questions related to various scenarios experienced by OHPs when providing oral health services to the community. The 12 questions asked during the in-depth interview were as follows: (1) How is your work now? (2) What suggestions can you make so that your work becomes much easier? (3) Do you manage to give oral health education to every patient that comes to you? (4) Are you able to provide scaling and polishing treatment to all the patients who need treatment? (5) Do you get time to sterilize and reuse instruments for scaling and polishing according to need? (6) Do you get time to give oral hygiene instructions to patients after a procedure? (7) Are you satisfied with the quality of treatment that you are offering to your patients? (8) What happens when one of the equipment in the dental clinic stops working or needs repair? (9) When dental materials like polishing paste finish, is it replaced immediately? (10) Do you feel that you are at risk while providing treatment? (11) In your opinion, what would decrease your workload? (12) What are your suggestions to improve oral hygiene treatment facilities in the dental clinic?

Following informed consent, the primary investigator (EN) conducted the interviews with the OHPs in a private room. The in-depth interviews were conducted in English and interpreted in Kinyarwanda, the local language, when necessary. Each interview lasted around 30 minutes. The responses of participants were audio recorded, transcribed verbatim, and saved as individual Microsoft Word documents soon after the interview. At the end of the interview, an audit of the dental equipment was performed using the observation checklist.

Data analysis

Descriptive statistics were used to analyze the quantitative data using percentages and frequency distribution. The dichotomous responses, 1 equals *yes* and 0 equals *no*, to identify the availability, adequacy, and functionality of the dental equipment, instruments, or material needed for scaling and polishing were recorded. Data were entered manually on an Excel spreadsheet and then imported into Stata version 16 (manufactured by StataCorp LLC in

USA) for analysis. For the qualitative data, the recorded interviews were transcribed and imported into NVIVO software (manufactured by QSR International) for a detailed analysis.

The interviews were analyzed using thematic content analysis [24]. The first step in the analysis was to look at the participants' own words and phrases without preconceived notions or classifications. We examined in deep the responses of each participant's answer to all the questions.

To ensure trustworthiness, two additional researchers, an experienced qualitative researcher in health systems and a dental specialist, participated in the development of the codes by reading the participants' responses independently from the primary researcher to establish an inter-coder agreement. Once the initial analysis was completed, the team liaised to discuss the codes generated independently and to reach an agreement on the codes and themes.

Ethical statement

The research received ethical approval (M220213) from the University of the Witwatersrand Human Research Ethics Committee (Medical). Additionally, permission was obtained from the relevant healthcare authorities, including the Rwanda Institutional Review Board (IRB) ethical committee (No. 234/CMHS IRB/2022) and the National Health Research Committee (No. NHRC/2022/PROT/26). The written informed consent form was obtained from the participants.

Results

Description of the study sample

Seven facilities were audited for the availability, adequacy, and functionality of equipment for preventative dental services. Furthermore, 14 OHP from these facilities were interviewed about the challenges they face when providing oral health services to the community.

Frequency distribution of health facilities with essential dental equipment and instruments

Table 1 shows that five health facilities had dental chairs but only four of these chairs were fully functional. Only two health facilities had adequate dental chairs, dental lights, and dental

Table 1. Preventive dental equipment, instruments and material audit availability.

Equipment/instruments	Availability		Functionality		Adequacy	
	Yes	No	Yes	No	Yes	No
Dental chair	5	2	4	3	2	5
Dental light	5	2	4	3	2	5
Dental stool	5	2	5	2	2	5
Dental compressor	5	2	5	2	5	2
Suction lines	6	1	5	2	5	2
Sterilizing unit	7	0	7	0	7	0
Ultrasonic scaler unit	6	1	5	2	3	4
Ultrasonic tips	6	1	5	2	0	7
Manual scaling set	7	0	7	0	4	3
Suction tips	5	2	5	2	4	3
Instruments for polishing	5	2	5	2	4	3
Prophylaxis handpiece	5	2	5	2	4	3
Prophylaxis angle	5	2	5	2	4	3
Prophylaxis cup/brush	5	2	5	2	4	3

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stools. All health facilities had functional and adequate sterilizing units. The manual scalers were available and functional in all seven health facilities, and five facilities had available and functional equipment and instruments for scaling and polishing. However, the adequacy was low concerning the ultrasonic unit ($n = 3$) and ultrasonic scaler tips were inadequate. Functional prophylaxis handpieces, prophylaxis contra-angle, and prophylaxis cups/brushes were found in four of the facilities. Polishing material was also inadequate in three facilities.

Frequency distribution of health facilities with essential dental material. The materials for oral hygiene instructions, oral examination instruments and personal protective equipment (PPE) availability and adequacy from the facilities were analysed. Only two health facilities out of seven had a demonstration model, toothbrush, and dental floss for interdental cleaning during oral hygiene instruction. None of the health facilities used a mobile application for oral health education. All seven health facilities had dental probes, mouth mirrors, and dental trays, but only six had periodontal probes. However, all these instruments were adequate in only four health facilities. Six of the health facilities had all personal protective equipment and they were adequate. The mouth masks were available and adequate in all the health facilities.

Demographic characteristics of OHPs. Overall, the total number of OHPs was 14, with five based in health centers, three in district hospitals, and six in referral hospitals. Most respondents were dental therapists ($n = 11$), and the dental surgeon ($n = 3$). The females ($n = 9$) were predominant, and the majority of the participants were aged between 31–40 years ($n = 7$). The 41–50 age group included 4 OHPs, and in the 21–30 age group had 3 OHPs. The years of practice of the OHPs revealed that ($n = 6$) OHPs had more than 10 years, 6–10 and 1–5 years of experience had 4 OHPs respectively.

Emergent themes. Although overlapping, four broad themes emerged from the responses of OHPs in the in-depth interviews, shown in Table 2, and these themes are discussed in the following subsections.

Human resources

Apart from the OHPs working at the district hospital who reported that the patient/practitioner ratio was manageable, all the other OHPs complained about patient overload. In five of the health centers, there was only one dental therapist managing all the patients. The understaffing resulted in complaint-oriented service instead of comprehensive holistic dental management. Furthermore, the OHPs had to rush to clear the long queues and cannot not perform other treatments such as scaling and polishing or dental fillings since many patients have acute pain. In addition, ensuring good infection control can be challenging when the practitioners

Table 2. Themes that emerged from OHPs' experiences in Nyarugenge District.

Theme	Description
1. Human resource	• Poor OHP/patient ratios • Lack of dental assistants
2. Supply chain management	• Insufficient of equipment • Insufficient instruments • Insufficient dental materials
3. Patient education and service rendering	• Lack of public awareness • Delayed oral health care seeking practices • OHP workloads
4. Strategic management and administration	• Health system responsiveness • OHPs' attitudes and behavior (pleasant, rude, or caring attitude); • Management of service provision; inadequate or lack of communication

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are working alone without a dental assistant. The following comments by the OHPs gave a clearer picture of the situation:

"The number of patients is higher compared to the number of dental practitioners. Sometimes you have to rush in order to clear the line of patients." (Participant 2)

"When there are many, we sometimes don't do a deep intraoral examination and concentrate only on the chief complaint instead of doing a comprehensive oral exam." (Participant 5)

"Sometimes I am not happy due to the large number of patients. So I cannot satisfy all their needs. We can skip doing some treatments like scaling and dental fillings due to that number." (Participant 12)

"You understand that this is a big challenge. If we have to work as four hands and you are there alone, helping yourself, it is not correct." (Participant 11)

Another challenge expressed by the OHPs working at the district hospital and the referral hospital was the lack of specialists. The waiting list and time are long for patients who must be seen by a specialist, and it was reported that some patients with oral cancer have died while waiting for treatment. Furthermore, since there is no dental surgeon at the district hospital, even patients requiring simple endodontic treatments and impacted teeth removal are referred to the hospital. Unfortunately, when patients arrive at the referral hospital, they can be turned back because of lack of dental material, and then they must get another referral to the Rwanda Military Hospital. That was distressing for both the patients and the practitioners, as shown in the following comments:

"Bring also dental surgeons so that more services would be offered from here. Patients would receive a bigger package of dental care from here; references would be reduced." (Participant 3)

"I think they should train more specialists. Currently, we have only one maxillofacial surgeon dealing with accidents and emergencies. You find that a patient with orofacial cancer can die without even being examined by the specialist." (Participant 7)

It is imperative to recruit more OHPs for primary oral healthcare services because if this is not done, the quality of care offered in public health facilities will continue to be compromised.

Supply chain management

The OHPs reported that they do not have sufficient equipment, instruments, or materials to offer dental care to the community. The audit findings from the checklists showed that two health centers did not have a dental chair, and of the five health centers that did have a dental chair, only four had a fully functional one. At the referral hospital, only two chairs out of four were available and could be used for ultrasonic scaling. The situation was similar at the district hospital, where only one chair out of two was available, fully functional, and could be used for ultrasonic scaling. Three health centers had one dental chair each, but only two of these chairs could be used to perform ultrasonic scaling. In general, no dental clinic had adequate equipment for the number of patients. As shown in the following comments, the OHPs expressed that the lack of equipment, instruments, and materials impacts the oral healthcare they provide to the community:

"Concerning equipment, since we have many patients who need our services, it would be much better if we had more equipment. Currently, we have only one dental chair. It would be better if we had two of them. More equipment should be purchased to serve the population better." (Participant 8)

"Most of the time we don't have enough materials for all the patients. Some patients get good service while the others get lower service because some materials have finished." (Participant 9)

Competing priorities in hospital settings between dental services and other services, such as maternity or pediatric services, were cited by OHPs as reasons for the lack of dental resources. The dental equipment could be damaged and not be repaired, and consumables were finished and not procured, resulting in patients waiting a long time before receiving treatment. This is a challenge at almost all the surveyed health facilities. Usually, in public health facilities, tender and procurement processes take a long time, which means that some items that are received are used immediately because the waiting time was so long. The following comments by participants express this challenge:

"That is also a challenge. It doesn't mean that the materials are nowhere to be found, only that the process is long... sometimes you get them too late when it is no longer possible to help the patients. You can make a request today and wait a whole year for delivery." (Participant 9)

"The priority is given to the maternity, pediatric, and neonatology services. The dental service lags in the process of supplying... we always wonder if the dental service is futile or is not generating money so that its revenues cannot help to buy a scaler. If a scaler has been functioning for like two years, it is not understandable that the money generated during that period cannot buy another one to replace the damaged one. That is always a challenge." (Participant 1)

Even though six of the seven dental clinics had ultrasonic scaler units, most of them did not have enough scaler tips, which led to overuse until the tips were no longer efficient. In many of the facilities, they can book only two patients per day, despite the need to book more patients. The availability and functionality of the scaling instruments were optimal, but when compared to the number of patients who needed this treatment, it was inadequate. The problem is worsened by the fact that dental clinics are no longer allowed to have a sterilizer on the premises, which would have allowed them to sterilize scaling instruments between patients. The new protocol means sterilization can only be done at the main sterilization unit of the hospital or the health center. These new protocols result in delays in the sterilization process and the availability of sterile instruments, negatively impacting services. The OHPs described the problem as follows:

"These types of equipment and materials should be in enough because many patients are having a lot of calculus. Sometimes even when they have another chief complaint, you might wish first to clean their teeth before proceeding with the filling or the extraction in order to work in a safe oral environment." (Participant 3)

"I had requested 30 scaler tips, but I have only two. But even those two are no longer functioning perfectly because they are overused." (Participant 11)

"I become stressed because I see patients who need (preventive) services. Telling someone to come back after one month is very frustrating. You would like to serve them immediately but due to the shortage of equipment, you are obliged to give a rendezvous one month later." (Participant 11)

"We sterilize in a big container from the autoclave at the theatre and in the morning, they bring them back and put them in small boxes." (Participant 5)

After scaling, it is necessary to polish dental surfaces to prevent a rapid re-accumulation of calculus. However, only three sites had the necessary polishing paste, and most of it was of poor quality and could not perform good polishing. The service of polishing teeth posed another challenge because it is not covered by the CBHI scheme, which is mostly used in public health facilities. Therefore, many patients attending public health facilities cannot afford to pay for teeth polishing services. The result is unpolished dental surfaces that attract dental plaque and calculus more quickly, which discourages patients and makes them believe scaling is more harmful than beneficial to their oral health. The following comments by the participants explain this problem:

"We would also like to get the polishing paste whenever we need to use it. People start to be aware and to look for better oral hygiene." (Participant 3)

"The request of consumables is done on time, but since we are in a public hospital, the process of delivery is very long so at given times we stop doing some procedures because dental materials are not there. That process causes us to experience stock-outs." (Participant 2)

"The only consumables they care to avail are those linked to tooth extraction. But for the others, the administration is reluctant." (Participant 12)

The adequacy of diagnostic dental instruments was low in all seven health facilities considering the number of patients received daily, except for personal protective equipment. The COVID-19 pandemic improved the availability and adequacy of personal protective equipment in all health facilities because administrators of health facilities realized the importance of personal protective equipment in protecting patients, practitioners, and colleagues.

Patient education and service rendering

The heavy workload of OHPs leads to them overlooking important practices such as oral health education. The OHPs said that it is almost impossible to give oral health education to every patient they examine. The OHPs give superficial oral health education to patients with halitosis or poor oral health status, but only OHPs working in two health facilities said they found time for thorough one-on-one oral health education. This is possible because another dental therapist was recently recruited at one health center, which means the district hospital staff are no longer overloaded. This resulted in improved OHP/patient ratios. This proves that the will to do oral health education is there but that the practitioner/patient ratio makes it impossible. However, the OHPs confirmed they give postoperative instructions to every patient after treatment regardless of their overload. The following comments by the OHPs show the extent of the problem:

"It is not possible to give oral health education to every patient. Most of the time, we do it for patients with poor oral health status or with halitosis. That is when we tell them that they have to brush their teeth." (Participant 5)

"We only tell them to remember to brush their teeth in the morning and at night before going to bed. Only that." (Participant 7)

"Giving oral health education to every patient is challenging because patients are many. You only tell them about the act itself you are about to do for them or, after completing the procedure, giving them related instructions. Otherwise, it is very challenging unless you do mass education, but they don't come at the same time." (Participant 4)

"There are also some people who don't want to hear what you are telling them, thinking that you are wasting their time while you wanted them to acquire some awareness." (Participant 3)

Patients are unaware that it is better to prevent oral diseases than to cure them and that teeth can be cleaned professionally. They often realize that there are some deposits on their teeth and try to remove them with charcoal, which causes more dental problems like enamel abrasion. Most of the patients seek dental services because of pain. Even when OHPs see the need for scaling and polishing and gave them an appointment, the patients do not come for the treatment. According to the OHPs, most patients do not listen to the advice they are given during individual or mass oral health education and consider it a waste of their time. One OHP said that the reason for this is that there are no OHPs recruited in the community to teach them oral hygiene measures and to screen their mouths for early detection of diseases. Community oral health prevention should be established and consolidated because it will tackle the problem of oral health at the root, especially since individual dental self-care by tooth brushing, including interdental cleaning, is the most important preventive measure for periodontal disease and dental caries. Furthermore, patients should cooperate with OHPs and quit harmful habits such as smoking, alcohol, and drug abuse.

"There should be dental personnel affiliated in the community to educate people about oral health. That would be very good". (Participant 4)

Oral health education is also a challenge because of a lack of teaching aids and promotional material. Only one health center, managed by sisters of the Roman Catholic Church, had all the necessary didactic materials for oral health education. The facility had a big teaching model and a big brush they could use to clearly show all the parts of the oral cavity and how to clean them. Participant 8, who works at this center, said, "First of all, we have didactic materials in our office. We have a big toothbrush and a big model that we use to show them the technique for tooth brushing. We also show them the gum and the tongue on the model. You see that this model is showing all the parts of the mouth". The only other health facility with a small dental model teaching aide is the district hospital. At all the other centers, oral hygiene measures are taught using gestures, and it is impossible to verify whether patients understand what they are taught. The OHPs did not even have dental floss to show patients how to clean interdental spaces and had to teach patients only in theory. The lack of time due to patient overload and the lack of didactic materials negatively affect oral health education, which is the basis for oral disease prevention. Participant 5 explained it as follows:

"We don't have typodonts and materials which would help us to explain the technique for dental brushing. When we do it only in theory, we are not sure of the outcome. Didactic materials should be available on our consultation tables, but we don't have them ... we only give oral health education in theory, but we cannot verify if they understood well or not." (Participant 10)

The large number of patients seeking dental care reflect the oral health status of the community. The poor oral health status of the community could be improved if oral health education is improved through measures such as active, practical education through people's mobile phones. All the interviewed OHPs were amazed by such an idea and recognized that the application would make their job much easier because patients would come to them with some knowledge about oral health and ask questions to clarify the information they received on their phones. If the information is updated regularly with clear audio-visual materials, it will positively impact people's oral health, even in remote areas. The following comments show the OHPs reactions to the idea of a dental mobile application:

"People would be aware of when and how to perform oral hygiene and consequences of poor oral hygiene." (Participant 14)

"That is where that application would play a role in raising the awareness of our clients about oral health. The communication between dental patients and dental practitioners would be smoother. That wouldn't take us a lot of time trying to convince them about the best treatment." (Participant 1)

"That is why the application you were telling me about would be very useful because problems start at the community level, not at the health facility . . . since oral problems can be prevented, and the application can help them in that, it would be good if it was installed in people's phones and was used. It would remind them how to clean the mouth." (Participant 4)

An oral health education mobile application would promote community oral health awareness, help children, youth, adults, and even old people maintain their oral health and show them early signs of disease so they seek dental care in time. It would inform the population of the importance of regular dental check-ups instead of waiting to get dental care only when in pain. It would also improve people's oral health literacy, which would ease their communication with OHPs and increase their compliance with preventive measures.

Strategic management and administration

Many of the challenges faced by the OHPs could be addressed by management. Management plays a crucial role in staff recruitment, motivation and the procurement of proper dental equipment and materials. Management's role is also related to reducing patients' waiting time by increasing the number of working stations by supplying dental chairs and employing dental assistants. A good workplace should be a safe environment for both patients and practitioners, and OHPs should feel valued by the administration.

"It is challenging to serve such a big number of patients while we don't have enough working stations so that each one might work from his/her dental chair". (Participant 9)

Poor strategic management and administration were particularly observed at two health centers where OHPs lacked basic equipment such as dental chairs and basic instruments despite constant requests. At one health center, dental extractions and manual dental scaling are performed using archaic equipment. The OHP working there reported that requests sent to the Ministry of Health can take long and that they often receive no response.

"Here, we don't have dental equipment. We have asked for them, but we haven't yet received them . . . I would be happy if they bought for me new and modern equipment". (Participant 6)

At another health center, the dental chair had been taken during the COVID-19 pandemic and given to another health center in a different district because the health center had become an isolation center for COVID-19 patients. The participant explained that they have asked the administration to return the equipment but to no avail:

"If the dental chair and all needed instruments, equipment, and materials were available so that when the patient comes and needs any treatment they might get it, this would satisfy me". (Participant 10)

The OHPs are frustrated because their requests for dental instruments and materials are ignored by management. The OHPs believe that the lack of dental representatives in the procurement committees is the reason their orders are not approved. Procurement and supply chain committees/personnel are unfamiliar with dental jargon, instruments, consumables, and requirements and do not consult the OHPs when they require information. The OHPs explained the problem as follows:

"They don't supply us with dental materials on time so that we might serve our patients in a good and satisfying way." (Participant 3)

"Another thing, even when they provide, usually they bring a different item from the one you requested. As a recent example, we requested drilling burs and they brought polishing burs, while we needed inverted cone bars." (Participant 2)

Only health facilities managed conjointly with the Roman Catholic Church seem to prioritize dental services and procure what was needed, as shown by the following comments:

"There is no problem here even for equipment. I can say that our administration is valuing dental service even more than I do." (Participant 8)

"Concerning sterilization of instruments, we never lack instruments here. We are privileged because this health center belongs to the Catholic Church so basic instruments are there. Even though they cannot be enough for all the patients, we clean and sterilize them. Our instruments are safe because we have a sterilizer in which instruments are ready in 45 minutes. We don't have any problem with that." (Participant 8)

All dental equipment, instruments, and materials, including those for preventive services, must be made a priority in managers' demand and operational plans. It was found that when the administration is supportive, the working environment is improved and OHP satisfaction is high. This was confirmed by the staff at the referral hospital who reported that they benefit from a supportive working environment. Their equipment was well-maintained and more staff were being recruited to assist in the X-rays section. When dental equipment remains unrepared for a long period, it shows that the dental services, OHPs, and patients are not valued.

"Our department has an appointed technician, a medical engineer charged with repairing dental equipment. He is based in the department of maintenance, but when we call him, he immediately comes. He is skilled. Not many things are difficult for him." Participant 13

During the interviews, the OHPs were asked what would ease their work. Firstly, they said they would like the patient/practitioner ratio to be reduced by recruiting more dental staff and

by increasing work stations. This will allow them to work the recommended hours instead of working extra time. Secondly, they would like to have the necessary equipment and materials, a better salary, and tea or coffee breaks at work because even though they like their job, it is hard work. Thirdly, although the organogram of the health centers plans for only one dental therapist, they want it to be revised so that at least two OHPs are hired per facility because the primary healthcare facilities are extremely busy.

Discussion

This study evaluated oral health services and the challenges faced by OHPs when providing oral healthcare in Rwanda. The study found that there were variations across the seven health-care centers in terms of human resources, supply chain management, patients education and service rendering, as well as strategic management and administration.

When considering the results of the checklists and the interviews used in the current study, it appears that one of the biggest challenges faced by OHPs while delivering preventive oral health services was linked to human resources. There was a shortage of personnel, such as dentists, specialists and dental assistants. This impinges on oral health service delivery, which is a factor in patient and practitioner satisfaction. This concern has also been raised by researchers in Nigeria and India, where it was found that there is a limited number of dentists compared to the number of people who need dental care [6, 25, 26]. The challenge of understaffing has also been identified in many other low- and middle-income countries, and this limits access to oral healthcare [17].

In addition, most OHPs were dental therapists, and there is a scarcity of dentists and specialist OHPs. The situation is different in South Africa where oral health services are provided by oral hygienists, dental therapists, dentists, and various dental specialists [7]. It was also different from what was reported by a study performed in 47 WHO African countries that found that there are more dentists than dental assistants and dental therapists [5].

Another challenge highlighted in the present study was linked to supply chain management, where it was found that there was a lack of adequate dental equipment, instruments and materials, which was impacting the delivery of preventive dental care [27]. A study performed in Fiji identified the same challenge where OHPs complained of a lack of proper equipment and materials because the available materials were often of poor quality, and this prevented them from performing good-quality work. OHPs in Fiji revealed that they could not offer all services within their scope of practice because they did not have the necessary resources [28]. Similarly, in India, public facilities have been reported to be poorly maintained or to have outdated dental equipment [25]. In the current study, many of the health facilities did not have polishing paste, supposedly because it is not covered by CBHI and patients cannot pay for it themselves. Apart from the polishing paste, periodontal probes were also absent in one health facility and prophylactic prophy angles and prophy cups or brushes were inadequate in general.

However, the results of the current study differ from the results of a study conducted in Tanzania, where only a quarter of facilities had fully functional dental units. OHPs felt that their profession was being neglected [17]. This feeling of being undervalued was shared by the participants in the current study, where most of the OHPs felt that dental services were not valued, and therefore, there were often lags in the procurement process, particularly for preventive equipment and materials. Similar results were reported in Nigeria, where it was found that in the allocation of health resources, decision-makers pay little or no attention to oral health prevention programs because oral healthcare is seen as insignificant compared to other health areas [6]. Similarly, in India, it was found that when primary healthcare systems are

implemented, dental health is not included, leaving dental healthcare far behind other health services in the procurement process [25].

Patients' education and service rendering was another challenge identified in the present study. In fact, participants revealed that it was very challenging and quasi-impossible to provide a full package of oral health education to every patient. They only managed to give postoperative instructions and do some chairside oral health education, especially related to the treatment rendered. Needleman et al. highlights that postoperative oral hygiene instructions may be more important than mechanical plaque removal itself [23, 29]. However, oral health education is vital and it should be comprehensive. Its importance was demonstrated in Honduras, where it was proven that education can help prevent oral diseases because it is key to behavioral change [30]. Communities should be encouraged to adopt healthier lifestyles to live longer and healthier lives [31].

The patient's lack of knowledge and awareness about oral health results in seeking dental care only when they are in pain, and at that time, more invasive and expensive care is necessary. This leads to periodontal problems often being discovered at a late stage when the teeth have already become mobile. In fact, patients worry about their oral health when it becomes painful, and they often visit OHPs with complications from dental caries [26]. The literature shows that early check-ups and regular preventive care reduce the need for dental operative services [32, 33]. Therefore, in the present study, when asked about the mobile dental application, the participants were eager to see a mobile application installed on patients' mobile phones to continuously offer updated oral health information to people, even in rural and remote areas from which most patients come. In fact, it is believed that mobile phones offer a promising strategy for dentists to reach the public and deliver low-cost oral health education and promotion. A mobile application for oral health education has been proven to be effective in teaching patients how to take care of their oral health at their convenience time and place [34]. The application can be used to teach the population how to maintain good oral health, proper diet and nutrition, and the importance of routine dental check-ups [35]. If people know how to prevent oral diseases, there will be less dental patients, and patient/practitioner ratios will improve [33]. The importance of oral health promotion and education has been also highlighted in other studies. Interventional studies performed in different countries demonstrated that the attitude of parents who were taught about the oral health of their children in the intervention group improved and contributed to a significant increase in the oral health status and oral hygiene of their children, while in the control group, children had more dental caries on their deciduous molars [36–38]. This confirms that strong oral health promotion and education is the basis for oral health solutions.

In the present study, the findings showed that another challenge faced by OHPs is linked to strategic management and administration. In fact, it is the responsibility of health facility administration to ensure the recruitment of enough staff and the procurement of dental equipment, instruments and materials. However, even the few dental personnel who are available feel demotivated. Even though OHPs reported that they love their profession, they could not deny that it is tiresome, and therefore, they would appreciate and be more motivated if they received financial bonuses and incentives such as tea breaks during work hours. Suga et al. found that dentists are willing to provide dental caries preventive measures if their payment schemes were fairer [33]. The management of public health facilities should review their planning system so that dental services are equipped with essential equipment, basic dental materials and instruments, and proper human resources.

The management should also advocate for patients in insurance companies or provide standard required treatment regardless of the insurance cover. In this study, it was discovered that the fact that dental polishing is not covered by CBHI discourages dental practitioners from

providing dental polishing treatment, which hasten the dental plaque accumulation on scaled dental surfaces. The impact of medical insurance on dental service accessibility has also been raised by Ramraj et al. and Uguru et al. because they found that not only low-income groups but also middle-income groups struggle to access comprehensive dental care because some acts are not covered by medical insurance [6, 39]. Therefore, it is not enough to have health insurance, and the insurance should also cover at least all basic dental services, such as dental polishing [40, 41]. The problem of health insurance covering only a few dental procedures was also found in Nigeria, where some treatments are not provided due to lack of insurance coverage [6]. The CBHI should be encouraged to cover polishing because it is not very expensive. Basic oral healthcare coverage, including prevention, is patients' right. Efforts must be made by the management to support and advocate for preventive oral health service coverage, such as polishing, through the CBHI. This is highlighted by Bastani et al., who emphasized that policymakers in low- and middle-income countries should aim to improve populations' access to oral and dental services through advocacy for comprehensive insurance packages because millions of people in developing countries cannot afford basic dental treatments [42]. Hayashi et al. said that dentistry should move from an increasingly unaffordable curative model to a cost-effective evidence-based preventive model [31].

Limitations

The limitations of this study were that participants were recruited from a single district and only from government institutions, which means the results cannot be generalized to the entire country or private facilities. The quantitative data that was measured using an observation checklist was not all-inclusive, and some of the equipment/consumables required (e.g. Restorative materials, airtors) were not included in the audit. The study checklist focused on preventive oral hygiene services and required materials and equipment used for scaling and polishing.

Conclusion

The challenges faced by OHPs in Nyarugenge District were related to the following areas: human resources, supply chain management, patients' oral health awareness and service rendering, and strategic management and administration. However, if one looks closely, it appears that all these challenges can be addressed by proper management of the health facilities. Proper and optimal strategic management of public health facilities would make an effort to recruit enough personnel which would free time for OHPs to provide oral health education and other preventive measures and to do comprehensive oral examinations, which would allow early detection and, thus prevention, of oral diseases [43]. Furthermore, the management of health facilities should ensure the availability of dental equipment, instruments and materials for oral disease prevention and remember to prioritize community oral health promotion and education in order to raise the awareness of the population towards oral health. Well-established community preventive interventions such as a dental mobile application would help improve patient/provider ratios because it would raise awareness about oral health and help people adopt healthy behaviors. Finally, the management of health facilities should also make advocacy for the population so that more dental services would be covered by health insurance, especially the CBHI, which would allow OHPs to offer oral health services without constraints.

Supporting information

S1 Dataset.
(ZIP)

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The Feasibility and Acceptability of a Mobile Application for Oral Health Education Among Adults in Rwanda

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Background: Mobile technology health application (mobile Apps) can assist people manage their health and wellness, encourage healthy lifestyles, and provide valuable information whenever necessary.

Objective: This study aimed to evaluate the feasibility and acceptability of a mobile App for oral health education among adults in Rwanda.

Methods: This was a descriptive cross-sectional study. A total of 111 adult participants evaluated the acceptability and feasibility of the BrushDJ mobile App after using it for three months. At the end of this period, an online survey was conducted using a structured questionnaire consisting of questions on demographics, habitual oral health, assessing acceptability, and assessing the feasibility of the mobile App. Descriptive statistics were performed to analyse demographic characteristics, the feasibility and acceptability of the mobile App. Bivariate analysis using the Chi-square test was performed to detect significant associations amongst the variables.

Results: The response rate was 81% (n=90) of 111 participants who took part in the study, with the majority of participants 44.44% (n=40) aged between 18 and 27 years old. Just over half of the participants were male 51.11% (n=46). The mobile App was found to be highly acceptable (87.78%; n=79) and considered highly feasible (84.44%; n=76) by most of the participants. The differences in acceptability and feasibility across education levels were statistically significant (p=0.000 for acceptability and p=0.038 for feasibility).

Conclusion: The study revealed that the mobile App for oral health education (BrushDJ) was highly acceptable and feasible among the participants. The mobile App had a user-friendly interface and comprehensive guidance on oral hygiene procedures facilitated by its diverse and well-integrated functions.

Keywords: mobile technology application, oral health education, adults, feasibility, acceptability, BrushDJ

Background

Oral health is an essential part of overall well-being. However, many adults lack adequate knowledge and practice for good oral hygiene. Patients have traditionally accessed advice about their oral health from the dental team, but this has limitations such as inequalities and disparities in oral health services, especially to remote and underservice populations as well as lack of affordability to dental care. Mobile health applications that utilise mobile phones and other wireless technologies offer a promising alternative for delivering oral health education in a convenient, accessible, and engaging manner.¹ Mobile Apps have been shown to support education, business enterprise and service delivery. In health using information technology, consultations and self-care can be performed, to promote patients' autonomy and independence.²

Mobile Apps for oral health education have been found to promote regular tooth brushing, thus decreasing plaque and gingival index³ as well as improving and enhancing oral hygiene.⁴ Mobile phones are among the tools through which messages can be cascaded, including other electronic media such as emails as well as printed documents; news apers and pamphlets. Patients and healthcare providers can now stay in touch from any location to continue their follow-up, ask questions, collect information, inquire about or provide test results, schedule appointments, send reminders, and renew

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prescriptions.⁵ However, certain demographic factors, such as older age, living alone, having less education, earning a lower salary, and residing in a rural area were found to be linked to low utilisation of eHealth services.⁶

The BrushDJ oral health App is designed to motivate users to brush their teeth effectively to be used for both children and adults. The App provides basic oral health education through videos, text, and pictures tailored for various age groups. Its primary focus is to enhance users' oral hygiene by demonstrating appropriate techniques.⁷ The BrushDJ oral health App has been reported to motivate the participants to brush.⁸ In a study conducted in Brazil, people who received oral health education from a mobile oral health App have reported to retain the acquired knowledge better than those who received verbal health guidance alone.⁹ Mobile oral health Apps can offer oral health education in a fun way, which attracts children and youngsters. While playing, they can learn useful methods to promote their oral health.¹⁰ Therefore, all levels of the population can benefit from oral health education through smartphones, even in remote rural areas, provided there is internet coverage and availability of data to access the mobile App. Parents and caregivers can access information on how to maintain good oral hygiene for their children, thus helping to reduce early childhood caries.¹¹ Mobile Apps for oral health education have been developed elsewhere, and some studies have shown that they can effectively improve oral health knowledge and practices.¹² Based on the literature findings above, mobile technology has the potential to help the community to maintain their oral health. However, there is scarcity of information regarding mobile oral health App usage in Africa for oral health promotion.

The Government of Rwanda has started to invest more in information communication technology (ICT) to speed up the delivery of online health services.¹³ Mobile phone penetration in Rwanda is high, with over 80% of the population owning a mobile phone.¹⁴ Mobile health interventions have been successfully implemented in Rwanda for other health issues, such as maternal and child health.^{15,16} Rwanda has adopted online health consultations, allowing patients to receive expert advice from health professionals through phone calls. In addition, Rwanda has started a project called Connect Rwanda, which focuses on bringing one smartphone per family; many citizens have received their smartphones to access online services easily.¹⁷ Despite these encouraging strides, there are still gaps in the delivery of online oral health education and information to the communities. The widespread use of smartphones presents an opportune moment to improve oral health education and promotion interventions.

The aim of the study is to assess the acceptability and feasibility of using the mobile oral health Apps, BrushDJ, to enhance patients' oral self-care at home in Nyarugenge District of Rwanda. The study will contribute new knowledge on the feasibility and acceptability of a mobile oral health App designed to improve oral health. The null hypothesis (H0) is that the mobile application was not acceptable and feasible to use for oral health education. The alternate (HA) is that the mobile application was feasible and acceptable for oral health education. This study formed part of a larger doctoral study titled "Oral Health in Nyarugenge District of Rwanda: The Role of Mobile Applications in Oral Health Education".

Methods

Study Design

This study involved a cross-sectional survey designed to evaluate feasibility and acceptability of mobile App for oral health education. This was done through a survey directed to individuals attending public health facilities in Nyarugenge District, Rwanda.

Setting

Rwanda is one of Africa's 56 countries. It is divided into four provinces and Kigali City, which serves as the capital. The four provinces are subdivided into 27 districts, while Kigali City itself comprises three districts: Gasabo, Kicukiro, and Nyarugenge, according to government data.^{18,19} The study took place in July 2022 in the Nyarugenge District of Kigali City, Rwanda.

Study Population and Sampling Strategy

The study participants were recruited from adult patients who are 18 years old and above who met inclusion criteria such as owning a smartphone and being able to understand English or French. These participants have been recruited in our previous study which assessed oral health knowledge, attitudes, and practices (KAP) across three health centres in Rwanda. The KAP study recruited 426 participants, and the sample included only individuals who were 18 years old or older and lived in Nyarugenge District, Rwanda.²⁰ During sampling for the current study, some participants out of 426 were excluded (n=315)

because either they did not own a smartphone, they did not sign the informed consent, or they were not able to understand English or French. Eventually, 111 participants constituted the total sample size of the current study.

Inclusion Criteria

The included participants were those who agreed to receive the mobile app, signed consent, those who could understand English or French, and owned a smartphone capable to receiving the oral health education App.

Exclusion Criteria

The participants who did not sign the consent form, patients under 18 years, and those having a learning disability.

Measurements

We evaluated the feasibility and acceptability of the BrushDJ mobile App using a structured questionnaire. The questionnaire was adapted from reported studies.^{21,22} The adaptations were done to make the questions applicable for users' perceptions of the App's impact on their homecare oral health practices.

Demographic details were collected, with respondents being asked to provide information on their age, gender, and education level as well as their oral health habits. Additional details regarding App usage were also assessed. This included their perceptions, experiences and likeability of the App and its usefulness during the study period. A standard 5-point Likert scale was employed to measure these items, with responses ranging from Strongly disagree (+1) to Strongly agree (+5). The scoring was done on all questions and was analysed by combining all questions to obtain a total, which was converted to a percentage. An arbitrary cut-off points were set, where a score less than 70% was classified as "Less acceptable" / "Less feasible", and a score of 70% and above indicated "Highly acceptable" / "Highly feasible".²³

Ten items concerning the App's likability and engagement (its acceptability) were evaluated using the Likert scale. A composite variable was created by summing the scores of these ten items. The reverse scoring was done on five questions, and then acceptability was analysed by combining all questions to obtain a total score of 50 (100%). A score less than 70% was classified as "Less acceptable", and a score of 70% and above indicated "Highly acceptable".

Feasibility was assessed using a standard 5-point Likert scale, with response options ranging from Strongly disagree (+1) to Strongly agree (+5). The analysis was done by combining all questions to calculate a total score of 65 (100%). A score less than 70% was considered "Less feasible", while a score above 70% was considered "Highly feasible".

The items were pilot-tested with ten individuals. This involved having participants complete the entire survey and then discussing each item with them to ensure that the items were clearly written, understandable, and interpreted as intended. The general Cronbach alpha for the entire sample on acceptability variables was 0.712 and 0.961 for feasibility.

Procedure

A total of 111 adult participants received the BrushDJ mobile oral health App and were asked to use the app at home for a period of three months. The BrushDJ oral health App is designed to motivate users to brush their teeth effectively. The App provides basic oral health education through videos, text, and pictures tailored for various age groups. Its primary focus is to enhance users' oral hygiene by demonstrating appropriate techniques. Once BrushDJ is downloaded, it can be used offline without the need for a regular internet connection. However, during installation, participants were given an internet package for three months, even though they could access the App regularly without needing internet. At the end of the three months of using the App, an online structured questionnaire was used to collect data. The group who used WhatsApp received the questionnaire on their smartphone and filled in data in Google form. For those who were not available for the WhatsApp online follow-up data collection, a telephonic interview was conducted.

Data Analysis

Analysis was conducted using Stata software version 16 (StataCorp, College Station, TX). Descriptive statistics, such as frequency and percentage distributions, were employed to assess the feasibility and acceptability of the mobile oral health App. Bivariate analysis using the Chi-square test was performed to measure the level of association between demographic characteristics and the mobile oral health App acceptability and feasibility. The significance level was established at 0.05, with a 95% confidence interval.

Results

Demographic Characteristics of the Participants

The response rate was 81%, with 90 out of 111 participants taking part in the study. The age category 18–27 years was predominant, and over half of the participants were male 51.11% (n=46). Most of the participants 68.89% (n=62) had completed high school level of education (Table 1).

Table 1 Demographic Characteristics of the Participants

Demographics (n=90)	Frequency	Percentage
Age		
18–27 years	40	44.44
28–37 years	28	31.11
38–47 years	13	14.44
48–57 years	7	7.78
58 and above	2	2.22
Gender		
Male	46	51.11
Female	44	48.89
Level of education		
Less than high school	5	5.56
High school	62	68.89
College or university up to bachelor	22	24.44
College or university up to master or PhD	1	1.11

Frequency and Percentage Distribution of Oral Hygiene Behaviour

The majority of the participants brush their teeth twice a day, in the morning and at night, before going to bed (88.89%, n=80). Just over a third of participants use dental floss every day (36.67%, n=33), and most of them thought that regular oral cleaning, brushing teeth, and interdental cleaning are important (95.51%, n=85) (Table 2).

Table 2 Frequency and Percentage Distribution of Oral Hygiene Behaviour

Habitual Variables on Oral Hygiene	Yes n (%)	No n (%)
I brush my teeth when I wake up and before going to bed every day.	80 (88.89)	10 (11.11)
I clean my teeth (brush or rinse with water) after meals.	79 (87.78)	11 (12.22)
I use floss to clean my teeth every day.	33 (36.67)	57 (63.33)
I use an interdental brush to clean my teeth every day.	29 (32.22)	61 (67.78)
I think regular oral cleaning (brushing and interdental cleaning) is important.	85 (95.51)	4 (4.49)
I think I have good oral health.	71 (78.89)	19 (21.11)

Oral Health App Acceptability Among the Participants

Over half of the participants strongly agreed that they liked to use the App frequently, found the App not complex, think that they would not need the support of a technical person to be able to use the App and imagine that most people would learn to use the App very quickly (Table 3).

Table 3 Distribution of Oral Health App Acceptability Among the Participants

Oral Health App Acceptability Assessment (Usability)	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
I think that I would like to use this App frequently.	1 (1.11)	5 (5.56)	1 (1.11)	26 (28.89)	57 (63.33)
I found the App unnecessarily complex.	45 (50)	23 (25.56)	3 (3.33)	11 (12.22)	8 (8.89)
I thought the App was easy to use.	7 (7.78)	6 (6.67)	6 (6.67)	32 (35.56)	39 (43.33)
I think that I would need the support of a technical person to be able to use this App.	46 (51.11)	25 (27.78)	4 (4.44)	7 (7.78)	8 (8.89)
I found the various functions in this App were well integrated.	2 (2.22)	0	9 (10)	38 (42.22)	41 (45.56)
I thought there was too much inconsistency in this App.	36 (40)	35 (38.89)	8 (8.89)	8 (8.89)	3 (3.33)
I imagine that most people would learn to use this App very quickly.	3 (3.33)	7 (7.78)	4 (4.44)	30 (33.33)	46 (51.11)
I found the App very cumbersome to use.	41 (45.56)	33 (36.67)	3 (3.33)	8 (8.89)	5 (5.56)
I felt very confident using the App.	6 (6.67)	2 (2.22)	7 (7.78)	34 (37.78)	41 (45.56)
I needed to learn a lot of things before I could get going with this App.	34 (37.78)	29 (32.22)	4 (4.44)	13 (14.44)	10 (11.11)

Oral Health Mobile App Feasibility Among the Participants

Most of the participants strongly agree that they like the oral care video in the App, which helps them learn more about oral cleaning, and most of the participants confirm that the App is very useful (Table 4).

Table 4 Frequency and Percentage Distribution on the Feasibility of Oral Health App

Oral Health App Feasibility	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
I like the oral care video, which teaches me more about oral cleaning.	0	0	2 (2.22)	34 (37.78)	54 (60)
I like the App pointing out the focal areas in my mouth, which requires extra care.	0	0	5 (5.56)	47 (52.22)	38 (42.22)
I like the App showing the focal areas that require extra cleaning effort in the dental chart.	0	0	7 (7.78)	47 (52.22)	36 (40)
I like the App reminding me to use dental floss and an interdental brush to clean my teeth.	5 (5.56)	1 (1.11)	18 (20)	33 (36.67)	33 (36.67)
I like the App user manual, it makes the App easy to use.	9 (10)	4 (4.44)	23 (25.56)	21 (23.33)	33 (36.67)
I like the App rewarding with applause when achieving a toothbrushing session.	18 (20)	3 (3.33)	9 (10)	33 (36.67)	27 (30)

(Continued)

Table 4 (Continued).

Oral Health App Feasibility	Strongly Disagree n (%)	Disagree n (%)	Neutral n (%)	Agree n (%)	Strongly Agree n (%)
I like that the App provides important information about oral health.	3 (3.33)	1 (1.11)	6 (6.67)	28 (31.11)	52 (57.78)
I like the App allowing me to set reminders for tooth brushing.	11 (12.22)	2 (2.22)	6 (6.67)	36 (40)	35 (38.89)
I like the App reminding me to brush my teeth according to the time that is set.	11 (12.22)	2 (2.22)	6 (6.67)	31 (34.44)	40 (44.4)
I like the App reminding me to clean my teeth at least twice a day.	10 (11.11)	2 (2.22)	4 (4.44)	33 (36.67)	41 (45.56)
I like the App showing the progress of tooth brushing with an arrow, which directs me to brush my teeth in the same order.	0	0	6 (6.67)	33 (36.67)	51 (56.67)
I like the background music played in the App during the toothbrushing session.	13 (14.44)	5 (5.56)	6 (6.67)	38 (42.22)	28 (31.11)
The App was useful.	1 (1.11)	1 (1.11)	2 (2.22)	23 (25.56)	63 (70)

The Association Between Mobile App Acceptability, Feasibility and Demographic Characteristics

Table 5 shows the association between the App acceptability, feasibility, age group, gender and level of education. In terms of acceptability, the app was found to be highly acceptable by the majority across all age groups, though there were variations. Participants aged 18–27 years showed the highest rate of acceptability (92.5%), whereas those aged 48–57 years had the lowest (71.43%). The differences in acceptability among age groups were not statistically significant ($p=0.415$). However, the app's feasibility varied more notably by age. Younger participants (18–27 years) reported higher feasibility (82.5%) compared to older participants (48–57 years), who found it less feasible (42.86%), with a statistically significant difference ($p=0.013$).

Gender did not significantly impact acceptability or feasibility, with both male and female participants showing similar levels of high acceptability and feasibility ($p=0.126$ for acceptability and $p=0.623$ for feasibility). Education level significantly influenced both acceptability and feasibility. Participants with less than a high school education found the app less acceptable (20%) and less feasible (40%), compared to those with higher education levels, where acceptability and feasibility rates were notably higher. High school graduates showed an 90.32% acceptance rate, and those with college or university education up to a bachelor's degree had a 95.45% acceptance rate. The differences in acceptability and feasibility across education levels were statistically significant ($p=0.000$ for acceptability and $p=0.038$ for feasibility).

Table 5 Oral Health App Overall Acceptability and Feasibility Among the Participants by Demographic Characteristics

	Less Acceptable n (%)	Highly Acceptable n (%)	P value	Less Feasible n (%)	Highly Feasible n (%)	P value
Age group						
18–27 years	3 (7.5)	37 (92.5)	0.415	7 (17.5)	33 (82.5)	0.013
28–37 years	5 (17.86)	23 (82.14)		1 (3.57)	27 (96.43)	
38–47 years	1 (7.69)	12 (92.31)		2 (15.38)	11 (84.62)	
48–57 years	2 (28.57)	5 (71.43)		4 (57.14)	3 (42.86)	
58 and above	0	2 (100)		0	2 (100)	
Total	11 (12.22)	79 (87.78)		14 (15.56)	76 (84.44)	

(Continued)

Table 5 (Continued).

	Less Acceptable n (%)	Highly Acceptable n (%)	P value	Less Feasible n (%)	Highly Feasible n (%)	P value
Gender						
Male	8 (17.39)	38 (82.61)	0.126	8 (17.39)	38 (82.61)	0.623
Female	3 (6.82)	41 (93.18)		6 (13.64)	38 (86.36)	
Total	11 (12.22)	79 (87.78)		14 (15.56)	76 (84.44)	
Level of education						
Less than high school	4 (80)	1 (20)	0.000	3 (60)	2 (40)	0.038
High school	6 (9.68)	5 (90.32)		9 (14.52)	53 (85.48)	
College or university up to bachelor	1 (4.55)	21 (95.45)		2 (9.09)	20 (90.91)	
College or university up to master or PhD	0	1 (100)		0	1 (100)	
Total	11 (12.22%)	79 (87.78)		14 (15.56)	76 (84.44)	

Discussion

This study was the first to evaluate the feasibility and acceptability of a mobile App for oral health education among the adult population in Rwanda. The results of our study indicate strong support for the alternate hypothesis (H_a), which posits that the mobile application was both feasible and acceptable for oral health education among adults in Rwanda. This study showed that the acceptability and feasibility of the mobile app were higher among younger participants and were also influenced by education level, with those having less than a high school education reporting lower acceptability and feasibility compared to those with higher education. The predominating age group in our study finding was contrary to Underwood et al,⁸ who reported higher participation of 7–12 years age group in their study. The age group differences may be attributed to the sample selection of our study being limited to adults who were 18 years and above. Numerous mobile applications focused on preventing tooth decay primarily emphasize the promotion of effective oral hygiene habits and are tailored towards the young adult population.²⁴ The younger age group in our study were the 18–27 years old, and different educational attainment measured by levels of education did influence the usage patterns of mobile App. Different results were reported in India, where individuals' education level was not related to the usage of mobile applications for assistance with oral health care.¹¹ Hedge and colleagues have found that low literacy rates negatively affected the ability to read the information channelled through mobile phones.⁵ The study conducted in Kenya revealed findings similar that low literacy rates negatively affected the ability to read the information channelled through mobile phones.²⁵ Future larger studies are warranted to study how these exposure factors may influence the use of mobile oral health App in this setting, more so that age and gender have been evidence to influence individuals' information processing.²⁶ The participants in the present study reported good oral hygiene behaviours and positive attitudes, although there is room for improvement on some behaviours, such as use of interdental hygiene aides.

The participants in our study demonstrated a high level of acceptability of the mobile oral health App, which is slightly higher than the 73.7% reported in Boston and 77% reported in Malaysia.^{27,28} High acceptability of the mobile App implies intention to use the App as reported by Venkatesh et al²⁶ thus, our finding signals hope for the App usage. Low acceptability of the mobile App can indicate poor popularity, and has been reported that it can affect the utilization.²⁹ The high acceptability of the mobile App is commendable as it has resulted in frequent home use of the App in other settings³⁰ and, therefore, presents hope in oral health education and home care procedures to eliminate oral disease.

The strong agreement with frequent App usage aligns with research in the field of user acceptance of technology, which emphasizes the importance of perceived usefulness as a key determinant of adoption. Studies based on the Technology Acceptance Model have consistently found that users are more likely to adopt a technology if they perceive it as useful.³¹ The high proportion of participants expressing a desire for frequent App usage in our study suggests that they perceive the App as valuable and relevant to their needs, which is consistent with Technology Acceptance Model. The finding that participants did not find the App complex and believed they would not need technical support to use it echoes the importance of perceived ease of use in technology adoption. According to Technology Acceptance Model, perceived ease of use influences users' attitudes towards and intentions to use a technology.³¹ Research has shown that users are more likely to adopt technologies that are perceived as easy to use.³² Therefore, the absence of perceived complexity and the belief that technical support would not be necessary by the participants in our study suggests that the App is intuitive and user-friendly, which are critical factors in encouraging adoption.

Participants in our study believed that most people would quickly become adept at using the App, indicating positive perceptions of the App's learnability. This aligns with research emphasizing the importance of perceived ease of learning in technology acceptance.³² When users believe that a technology is easy to learn, they are more likely to adopt it and perceive it positively. In our study, it was observed that participants expressed a high level of confidence in utilising the mobile oral health App. The participants reported that the various features within the application were seamlessly integrated and user-friendly. Our observations align with the previously reported study, which indicated that individuals utilising oral health applications on their mobile devices exhibit great enthusiasm in endorsing and discussing their experiences.³³ This enthusiasm further extends to encouraging others to utilise the application, primarily due to its user-friendly interface.

Almost 85% of the participants in our study found the mobile App for oral health education to be feasible and usable. These results are commendable because it means the participants were able to navigate the App, understand the contextual meaning of the text and respond to the contents in the App. Feasibility of a programme or project is one of the initial steps necessary before a roll-out of a programme. According to Nicholas and Chinedum in 2017, feasibility determination is important to determine if a proposed programme or, project, service or business will be successful.³⁴ The high feasibility findings in our study reflect the positive reception of the mobile application among participants, indicating its potential to deliver oral health education effectively. Similar results were observed in a study involving the elderly, where mobile-based video education programs were found to be beneficial and effective. These programs improved patients' knowledge, satisfaction with education, and implementation of the educational content, ultimately enhancing their oral health.³⁵

The overwhelming agreement regarding the oral care videos by the participants in our study suggests that the participants found them informative and engaging. This aligns with previous research highlighting the effectiveness of multimedia interventions, such as videos, in promoting health education and behaviour change.³⁶ The videos likely served as valuable educational tools, providing visual demonstrations of proper oral hygiene practices and enhancing participants' understanding of oral care techniques. Participants in our study reported that they liked the reminders within the App, which prompt them to brush their teeth twice a day and perform interdental cleaning using dental floss or an interdental brush. The App reportedly conveyed valuable oral health information, and this creates hope that it may be a great tool for oral health awareness. Mobile Apps for oral health education are useful for adults, adolescents, and children because it has been shown that the information provided through smartphones by parents positively impacts children's oral health awareness.^{11,37} Feasibility determination is needed for the growth of the programme to advocate for its continuance.³⁴ Since mobile Apps are useful, they should be promoted, and their messages should be designed according to the end users. In addition, the content should be theoretically grounded and empirically validated.³⁸

The limitations of our study include its cross-sectional design and the fact that it focused exclusively on a specific group of participants in Rwanda. As a result, the findings may not reflect the broader views of the entire population of Rwanda regarding mobile Apps for oral health education. Therefore, it's essential to consider that some people may be receptive to using mobile Applications, whereas others might opt to maintain with the conventional clinical care offered in dental clinics. Moreover, the sample size and location do not represent the

entire city, which limits the generalizability of the findings. Additionally, the feasibility data were exclusively obtained through the survey questionnaire given to participants who used the BrushDJ App. Future extensive studies should include a more direct evaluation of the preferences of different oral health practitioners regarding the App's features alongside other oral health outcomes experienced by patients receiving the interventions to assess the effectiveness of the App.

Conclusion

Our study found that the acceptability and feasibility of mobile App for oral health education (BrushDJ) was high among the study participants. The mobile App for oral health received positive reviews from the user-friendliness nature. Our study findings have highlighted that the mobile App for oral health (BrushDJ) is a useful tool that might contribute to behaviour change and the adoption of adequate oral health measures. Population groups of all ages and backgrounds, even those in remote areas where the accessibility to dental services is challenging, can use the mobile App for oral health education.

Data Sharing Statement

The data presented in this study are available upon reasonable request from the corresponding author.

Ethical Approval and Consent to Participate

The Human Research Ethics Committee (HREC) (Medical) at the University of the Witwatersrand, Johannesburg, granted ethics approval (M220213) for the research. Approval was also secured from the Rwanda IRB ethical committee (No234/CMHS IRB/2022) and the National Health Research Committee (No NHRC/2022/PROT/26). All participants provided written informed consent. This study complies with the Declaration of Helsinki.

Consent for Publication

This manuscript contains no individual person's data in any form, and consent for publication is not applicable in this section.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

All authors declared no competing interests in this work.

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