Design of removable partial dentures fabricated in dental laboratories serving private and public health dental clinics in the district of Ekurhuleni, Gauteng province.

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Johannesburg, 2021

DEDICATION

To my loved ones.

DECLARATION

I, Ruqaiyah Ayub Daya, declare that this research report is my own work. It has been submitted for the degree of Master of Science in Dentistry in the Faculty of Health Sciences at the University of the Witwatersrand, Parktown, Johannesburg, South Africa. It has not been submitted before for any other degree or examination at this or any other University.

…………………………………………….

This 26 February 2021

ABSTRACT

Purpose

The purpose of this study was to assess and to compare the technical quality of removable partial dentures (RPDs) servicing both public and private sectors, in relation to biomechanically acceptable principles.

Materials and Methods

RPD prescription sheets, master casts and completed dentures of 114 cases were photographed to facilitate easier identification of components and data analysis outside the laboratory. Procedural and design-related information was completed on data capture sheets for each case. The recorded information was verified by an experienced prosthodontist. An additional prosthodontist was consulted for further analysis if information was unclear or controversial.

Results

30.7% of cases were from public and 69.3% from private sector. Acrylic RPDs were more frequently prescribed at 83.3% followed by metal-based RPDs at 16.67%. More maxillary dentures were requested (62.26%) than mandibular (37.2%). Only 0.88% of dentists had surveyed study models compared to 0% of dental technicians. Verbal instructions had been provided in 2.63% of cases, with written instructions given in 94.74% of cases. None of the dentists or technicians had provided design drawings. With design principles, rests were present in 21.93% of cases, rest seats were prepared in 3.51% of cases and clasps were present in 47.37% of cases. No significant association could be drawn between practice type and type of denture prescribed. Associations between design practices could only be established with the presence of rests. RPDs prescribed in the private sector were more likely to have rests compared to those from public sector.

Conclusions

The study suggests that principles of RPD design taught during undergraduate training are not being adequately practised in both private and public sector; and if practised the RPDs are not designed, nor constructed to the satisfaction of requirements guided by design principles. Further training of dental technicians and clinicians may be required.

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To Professor Owen, for his guidance and assistance.

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1. INTRODUCTION AND LITERATURE REVIEW

Introduction

In developing countries, a large percentage of patients are seeking treatment in order to replace part or all of their missing dentition. Possible treatment options include removable complete and partial dentures, fixed partial dentures, implants and implant-supported prostheses. Treatment is not always advocated to replace every missing tooth, especially if the occlusion is functionally stable and aesthetics are satisfactory (Witter et al, 1994; Sarita et al, 2003; Kanno and Carlsson 2006).

As technological advancements increase, treatment modalities such as implants and fixed prostheses have increased considerably, but are high-cost options and not always indicated for all patients. Conventional acrylic resin based removable dentures, therefore remain the most cost effective option for the majority of patients (Douglass and Watson, 2002; Pellizzer et al, 2012).

Removable partial dentures are indicated for the replacement of missing teeth to restore aesthetics and function. Fabricating removable partial dentures requires several clinical visits and multiple laboratory procedures (Academy of Prosthodontics, 1995; Owen, 2018).

1.1. Partial denture design principles

Removable partial denture (RPD) design principles have evolved since 1711, when partial dentures were first carved from a block of bone to replace missing teeth (Walisezewski, 2010). As the years progressed, with the aid of technology, as well as observations with regards to outcomes of wearing partial dentures, removable partial denture designs have changed considerably. Designing RPDs may pose a challenge, as there are a staggering 65 534 possible presentations of partial edentulism for each dental arch, this is if the only variable accounted for is the presence or absence of teeth. (Beaumont, 1989). Given that there are various variables at play when designing a denture, at present, there appears to be no single universally used set of guidelines on RPD design principles (Rudd et al., 1983; Jacobson, 1987), although a study conducted in the UK demonstrated that many RPD principles received the support of a majority of prosthodontic specialists (Davenport et al., 1996).

In this study, the extent to which RPDs met minimal standards of design was determined by the design principles outlined below:

- Evidence of casts having been surveyed by the dentists and/or dental technicians;
- The presence of articulated diagnostic casts;
- Written or verbal technical instructions given to the technician;
- Provision of denture design drawings by dentists and/or dental technicians;
- The presence or absence of rests in the final denture;
- The presence or absence of prepared rest seats on the master casts;
- The presence or absence of clasps in the final denture; and
- The presence or absence of guide planes on the master cast.

These design principles were assessed at the laboratory stage, in order to assess the extent to which the RPDs were able to satisfy these principles. These design principles have been derived from a number of studies (Rudd and O Leary, 1966; Runov et al., 1980; Boucher and Renner, 1982; Rudd et al, 1983; Chandler and Brudvik, 1984; Jacobson, 1987; Stratton and Wiebelt, 1988; Bergman and Ericson, 1989; Grasso and Miller, 1991; Becker et al, 1994; Witter et al, 1994; Academy of Prosthodontics, 1995; Davenport et al, 1996; Carr AB et al, 2005 ; Sarita et al, 2003; Dunham et al, 2006; Jones and Garcia, 2009; Koyama et al, 2010; Stilwell, 2010; Mothopi-Peri and Owen, 2018; Owen, 2018).

1.2. Importance of articulated diagnostic casts

Diagnostic casts are essential in enabling the clinician to reproduce structural and functional relationships of the dentition, allowing for accurate planning (Solow, 2013). If the casts cannot be articulated by hand, occlusal rims should be constructed and the intercuspal position should be recorded depending on the natural teeth present. Articulated diagnostic casts aid in assessing spatial requirements of the dentures when placing rests and designing the framework, ensuring no unplanned occlusal vertical dimension increase occurs (Academy of Prosthodontics, 1995).

1.3. Surveying and partial denture design by the clinician

Surveying has been defined as "the procedure of locating and delineating the contour and position of abutment teeth and associated structures before designing the RPD" (Rudd et al, 1983). This enables determining a path of insertion and withdrawal that is most favourable in providing active and passive retention. The design of the RPD is the responsibility of the dentist and should be planned in conjunction with the dental technician. A dental cast surveyor is necessary in order to determine the path of insertion, height of the contour line and to measure undercuts for clasp design (Rudd et al, 1983; Jones and Garcia, 2009).

Diagrammatic and written instructions should include framework design and saddle area extensions, occlusal rests, direct and indirect retention and reciprocation (Winstanley et al, 1996). The type of wire to be used for clasps should be indicated as well as dimensions of the wire and the depth of undercut in which the clasp should rest (Owen, 2018).

1.4. Rest seat preparations

The purpose of a rest seat preparation is to direct forces axially along the tooth (Boucher and Renner, 1982; Carr et al, 2005), to prevent movement in an occlusal direction, reducing trauma to the mucosa, and distributing occlusal forces. Rest location varies depending on the configuration of the remaining teeth (Stratton and Wiebelt, 1988). These should be prepared by a clinician on the occlusal surface of posterior teeth, or on the cingulum area of anterior teeth by a clinician before recording a secondary impression.

Rest seat design will vary according to the denture base material (metal or acrylic) or the component used (such as half-round wire for acrylic-based RPDs). A study conducted by Koyama et al (2010) found that patients that had adequate and sufficient rest seats, were overall more satisfied with their dentures than those whose dentures had inadequate support. Frank et al (2000) also showed that adequate support is one of the few criteria that correlated with successful wearing of mandibular Kennedy Class I RPDs.

1.5. Clasps

Clasps are direct retainers which aid in active retention of the prosthesis during function, by preventing RPD dislodgement. A well-designed clasp consists of a retentive arm with reciprocation, encircles more than 180 degrees of the tooth to resist horizontal dislodgement, such that the surfaces have tangents that diverge occlusally (Owen, 2018). The retentive arm has a flexible terminal third that sits passively in the undercut area (Rudd et al, 1983; Grasso and Miller, 1991; Owen, 2018). Reciprocation is either from a cast arm or from the denture base material, such that contact is maintained against the tooth to counteract the retentive force of the clasp arm (Rudd et al, 1983; Owen, 2018).

Clasps should be flexible enough to allow the RPD to be seated and removed without permanently deforming the clasp and without damaging the tooth (Bates, 1980; Frank and Nicholls, 1981; Matheson et al, 1986; Brockhurst, 1996; Waldmeier et al, 1996; Owen, 2018). The number of clasps should be sufficient such that minimal stress is applied to each abutment tooth. It has been suggested that the total retentive force required ranges between 300g and 1500g (Bates, 1963; Frank and Nicholls 1981), but no set formula exists to determine this, and each case should be treated individually regarding clasp design and the design of the RPD as a whole (Rudd et al, 1983).

Although clasps aid in retention, they should not be considered the prime objective of the design. Well adapted and extended denture bases, accurate framework fit, and properly prepared guide planes positively influence RPD retention independently or in combination with clasps (Rudd et al, 1983). Provided the abutment tooth is not jeopardised by their presence, intracoronal or extracoronal direct retainers may be acceptable (Carr et al, 2005).

1.6. Application of hygienic factors

RPD designs should incorporate minimal tooth coverage by framework components and elimination of redundant components without compromising biomechanical requirements (Jacobson, 1987). Mucosal reactions such as increased crevicular temperature, plaque formation, gingival inflammation and pocket depth have been observed when gingival margins are covered, thus an open major connector should be used where possible (Runov et al, 1980; Jacobson, 1987; Chandler and Brudvik, 1984).

1.7. Guide planes and guiding surfaces

The term guide plane is used to denote the prepared surface of a tooth adjacent to an edentulous saddle, and the term guiding surface denotes the equivalent surface on the denture (Mothopi-Peri and Owen, 2018). Together they provide guide plane retention, by increasing frictional resistance, limiting the path of insertion/removal as well as stabilisation against horizontal rotation of the denture and to eliminate food traps between the abutment teeth and RPD components (Stratton and Wiebelt, 1988; Carr et al, 2005). Guide planes need to be created so that they are parallel to the path of insertion. Close contact between guiding surfaces on the denture and guide planes on teeth, results in an increase in passive retention, to the extent that clasp arms may not be necessary (Mothopi-Peri and Owen, 2018).

Frank et al (2000) have shown that, apart from adequate support, guide plane retention was correlated with successful wearing of mandibular Kennedy Class I RPDs.

1.8. Factors relating to patient satisfaction

Frank et al (2000) investigated the relationship between standards of removable partial denture construction, clinical acceptability and patient satisfaction. They reported that patients were most dissatisfied with ill fit of partial dentures (76%), followed by iatrogenic damage caused by the partial denture (63%).

There was no statistical correlation when comparing individual standards of partial dentures to patient satisfaction. Individual standards of design and fabrication assessed within their study included rest form, base extension, force control, framework fit, base support, occlusion, stress distribution and retention.

When the relationship between tissue health and combined partial denture standards was explored, it was discovered that gingival inflammation was twice as likely when rest seats lacked positive form, the base was under-extended, insufficient rests were placed adjacent to a distal extension, and there was poor fit of the framework.

A similar study conducted by Cosme et al (2006), found that when comparing patient and professional evaluations, there was a correlation in terms of retention, chewing comfort, and

stability. These are variables are dependent on adequate design positively influencing patient satisfaction.

RPDs can improve aesthetics, function and oral health, if attention is given to maintenance of good oral hygiene, pre-prosthetic periodontal and restorative treatment, simple RPD design concepts and regular recall visits (Becker et al, 1994).

1.9. Denture provision in the public sector in South Africa

In the Ekurhuleni sub-district public sector, 1032 units of dentures (partial and complete) were delivered from the period April 2017 until April 2018. Dentists employed in the public sector have a quota system where a minimum of 6 - 8 units need to be completed and delivered per quarter in order to be reviewed at a minimal satisfactory level, amongst other targets. In order for the dentures to be fabricated, patients need to be above the age of 60 and receiving a State pension grant. Exceptions to this do exist for patients receiving a government disability grant, as well as minors under the age of 18 that may need anterior tooth replacement following tooth loss due to trauma. Currently provision is made only for acrylic partial dentures. Private dental laboratories are contracted to carry out the technical work in fabricating RPDs and these laboratories also serve practising private dentists.

One of the aims of a questionnaire study conducted by Dullabh et al (1993) was to compare differences in partial denture designs used by practising graduates with the principles and methods taught at an undergraduate level. The results reflected a distinct disparity between principles and methods taught to undergraduates and practices routinely applied after graduation. The study also reported that 82.3% of dentists instructed the laboratory technicians to design removable partial dentures. Diagnostic casts were not surveyed by 63.7% of dentists, and more than half (54.5%) did not mount diagnostic casts on an articulator. These results suggest that most dentists favoured techniques that required minimal time in the dental chair and that they delegated a great deal of their responsibility to laboratory technicians.

To date, no published studies have been carried out in South Africa to assess the technical quality of partial dentures in the public sector. From an ethical and human rights perspective, evidence-based dentistry is necessary to guide practitioners, ensuring rights of access to healthcare for patients and appropriate use of evidence, eliminating harmful consequences

(Khan, 2017). Over and above wasting state funding if patients are not using the dentures, the importance of assessing the quality of RPDs is vital, as ill-fitting RPDs can result in further tooth loss (Carlsson et al, 1970; Battistuzzi et al, 1987).

2. AIMS AND OBJECTIVES

2.1. Aim

The aim of this study was to assess the technical quality of removable partial dentures in relation to bio-mechanically accepted principles, using dentures that were fabricated in dental laboratories contracted to the Ekurhuleni district which also provided a service to the private sector, so that comparisons between sectors could be made.

2.2. Objectives

1. To assess the frequency of denture prescriptions sent to the laboratories prior to RPD fabrication.

2. To determine the extent to which the RPDs met minimal standards of design and fabrication in order to assess the technical quality of the dentures.

3. To compare the designs of RPDs made in the public, to the private sector.

2.3. Null hypothesis

The designs of removable partial dentures in dental laboratories serving public and private health clinics would be of similar quality to those taught at dental schools in South Africa.

3. MATERIALS AND METHODS

3.1 Study setting and design

This study was a cross sectional, descriptive study conducted on removable partial dentures during the laboratory stage of fabrication.

3.2 Study population

The study population comprised removable partial dentures fabricated in three dental laboratories in the Ekurhuleni district over 3 months. All acrylic and chrome removable partial dentures were included in the study, fabricated for both private and public sectors.

3.3 Materials and Methods

After receiving ethical clearances (Appendix A), from the Ekurhuleni Ethics Committee and Human Research Ethics Committee (Wits), three commercial dental laboratories in the Ekurhuleni district were selected for participation. A covering letter was distributed to the laboratories, in which the nature of the study was explained, and consent was obtained from technicians working in the laboratories.

Prior to delivery, each RPD prescription sheet, master cast and final denture was digitally photographed by the dental technicians in a way that allowed the number of existing teeth, the class of partial edentulism, support and retentive components to be identified.

In addition, the technicians participating in the study were required to examine RPD cases fabricated within the study period, in order to acquire the required statistical data, and to complete the data sheet for each case (Appendix B). No identification of patient names nor the clinicians were included.

The questionnaire sought information regarding: the choice of primary impression materials used, whether special trays were requested, materials used in secondary impressions, use of occlusion rims, types of articulators requested / type of articulators available, try-in procedures and if any dentures were sent back to the lab post-recall for adjustments to be made. A separate column for design and surveying was also completed by the technician. Where possible, at the master cast and prior to delivery stages, close-up photographs were taken by the researcher.

The photographic records of casts allowed for data to be analysed outside the laboratory. These were then examined and any outstanding aspects such as design features as per the data capture sheet were recorded. Features were examined again by an experienced prosthodontist in order to assess/verify technical quality, using the selected standards. In the event that there was any disagreement in interpreting the images and data capture sheet, an additional prosthodontist assessed the data.

4. RESULTS

4.1 Frequency of denture prescriptions sent to the laboratories

A total of 114 removable partial denture prescriptions were received by the laboratories from July to September 2019 at Ekurhuleni, and 69.3% were from private clinics as shown in Figure 1.

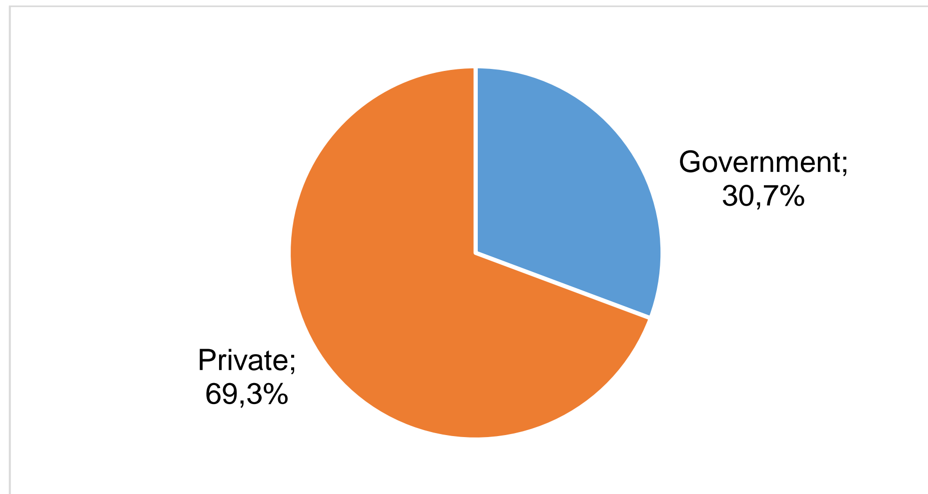

Figure 1: Denture prescriptions in private and public clinics (N=114)

4.1.1. The number of denture prescriptions that specified which teeth to replace

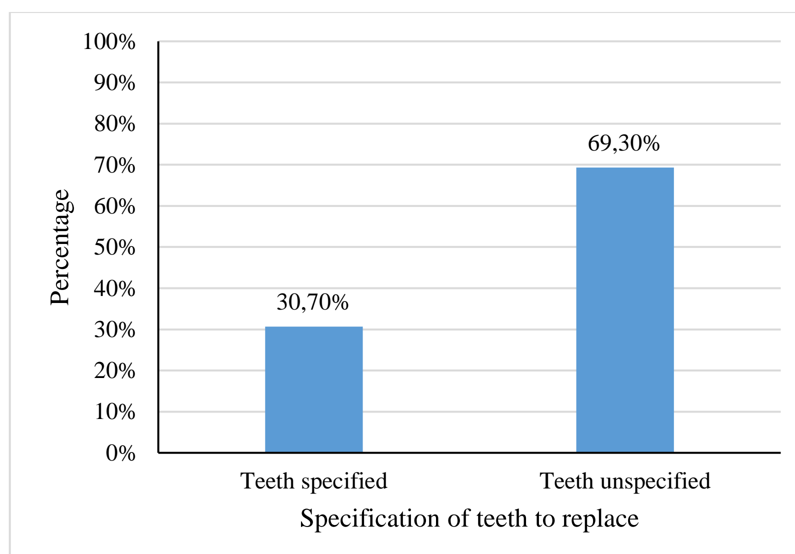

Figure 2: Specification of teeth to be replaced

4.1.2. The number of cases where clasps were specifically requested (teeth to be clasped remained unspecified for all prescriptions)

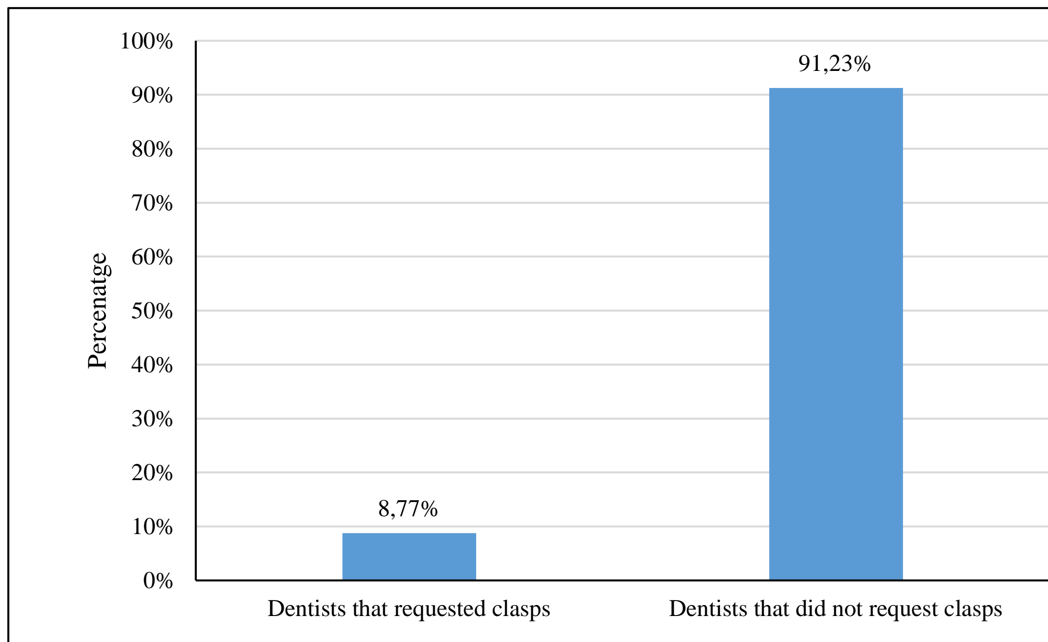

Figure 3: Requests for clasp placement

4.2 Type of denture base

Acrylic dentures were the most common type of denture base used: 83.3% of the dentures were acrylic-based while 16.67% were metal-based as shown in Figure 4.

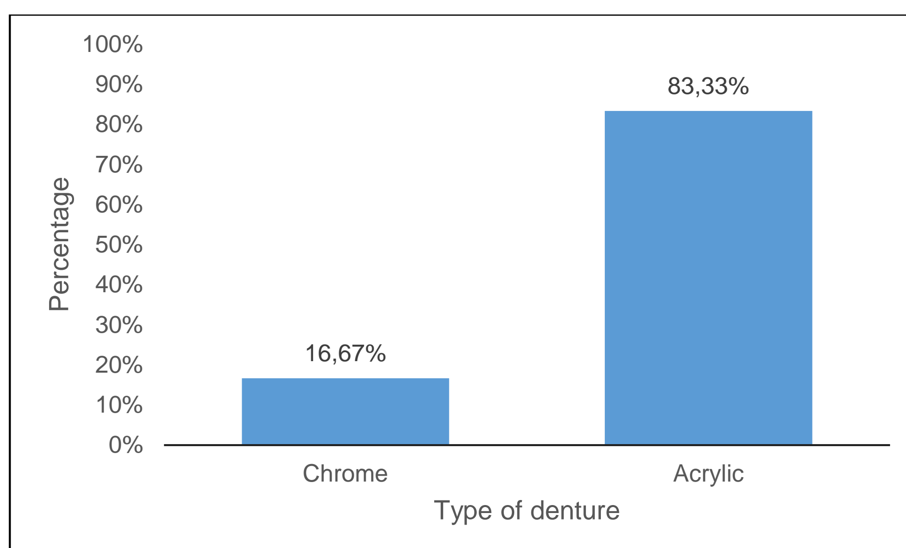

Figure 4: Type of denture base

4.3 Site of the denture

Maxillary (upper) dentures were the most commonly prescribed type at 62.26%, while 37.2% were mandibular (lower) dentures as shown in Figure 5.

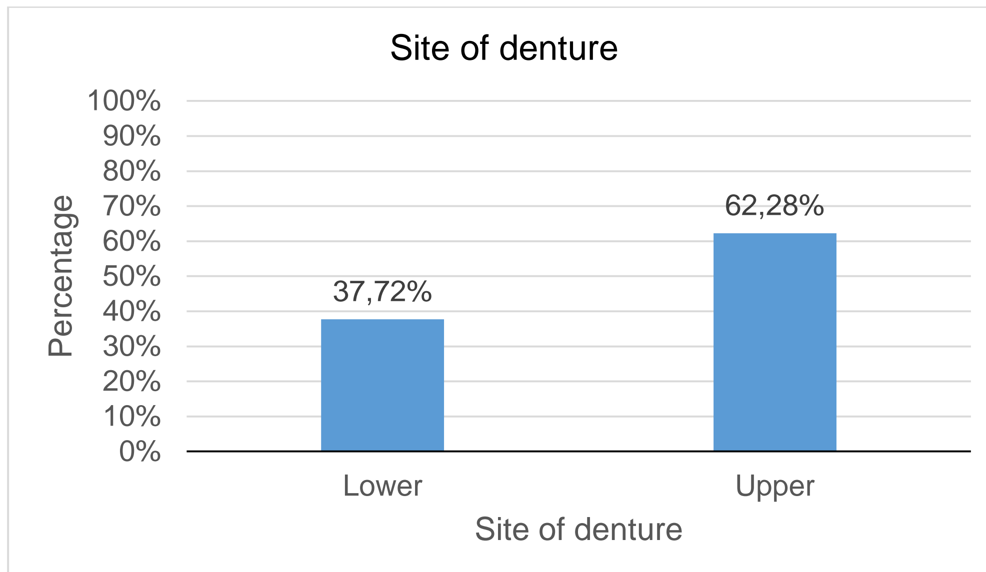

Figure 5: Site of denture

4.4 Extent to which the RPDs met minimal standards of design

The minimal standard designs were determined by:

- Evidence of the casts having been surveyed by the dentists and/or dental technicians;
- The presence of articulated diagnostic casts;
- Written or verbal technical instructions given to the technician;
- Provision of denture design drawings by dentists and/or dental technicians;
- The presence or absence of rests in the final denture;
- The presence or absence of prepared rest seats on the master casts;
- The presence or absence of clasps in the final denture; and
- The presence or absence of guide planes on the master cast.

The results of the survey on the minimal standards is presented in the bar charts below (Figures 6-15).

4.4.1 Surveying of models by dentists

Surveying of models by dentists was found in only 0.88% of the dentures as shown in Figure 6.

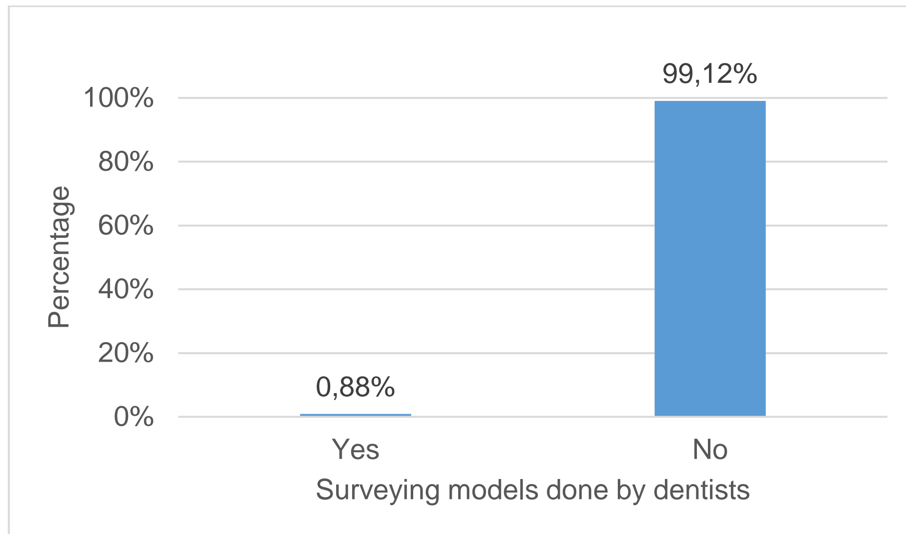

Figure 6: Surveying of models by dentists (N=114)

4.4.2 Surveying of models by dental technicians

No surveying of models was done by dental technicians (Figure 7).

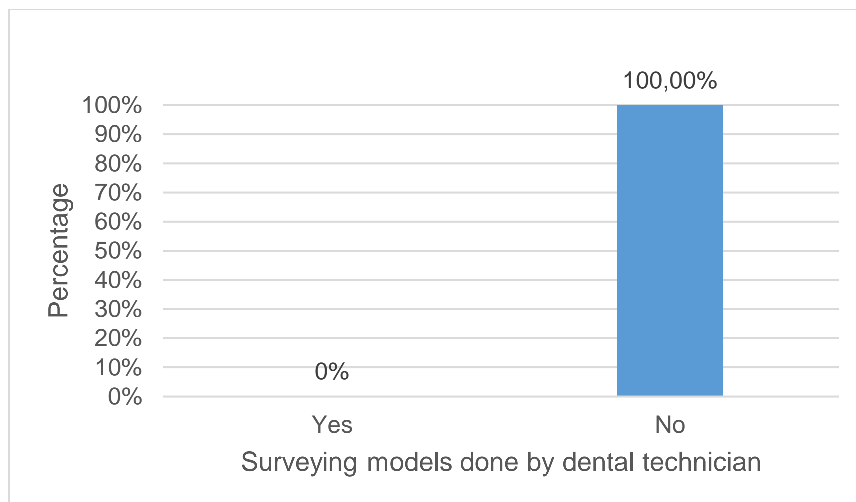

Figure 7: Surveying of models by dental technicians (N=114)

4.4.3 Presence of articulated diagnostic casts

None of the diagnostic casts were articulated, as shown in figure 8.

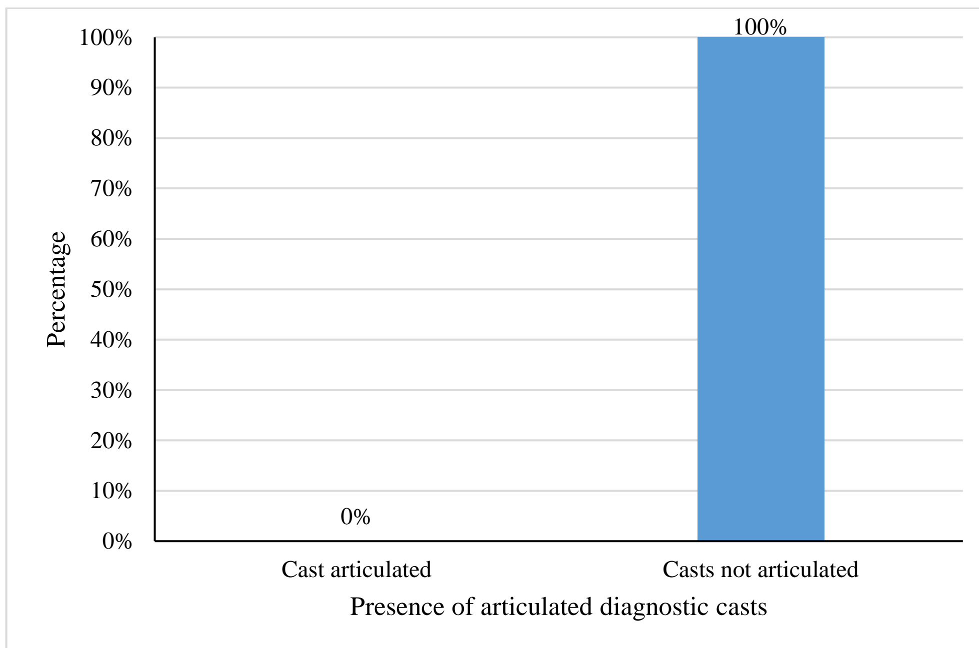

Figure 8: Presence of articulated diagnostic casts

4.4.4 Verbal instructions by dentists

Verbal instructions were supplied to the laboratory in 2.63% of the dentures as shown in Figure 9.

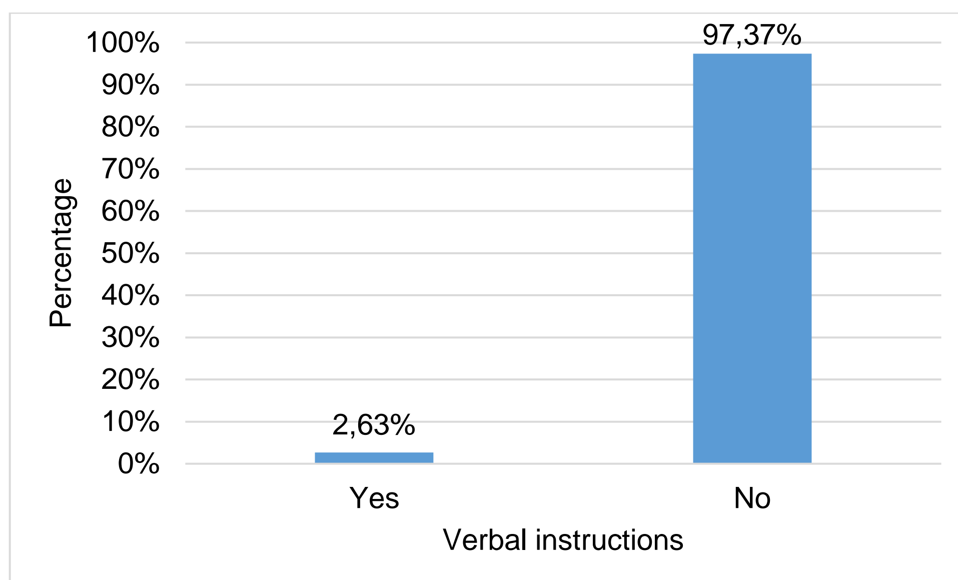

Figure 9: Verbal instructions by dentists (N=114)

4.4.5 Written instructions by dentists

Written instructions were given to the laboratory for 94.74% of the dentures on the standard laboratory forms, provided by the commercial laboratories.

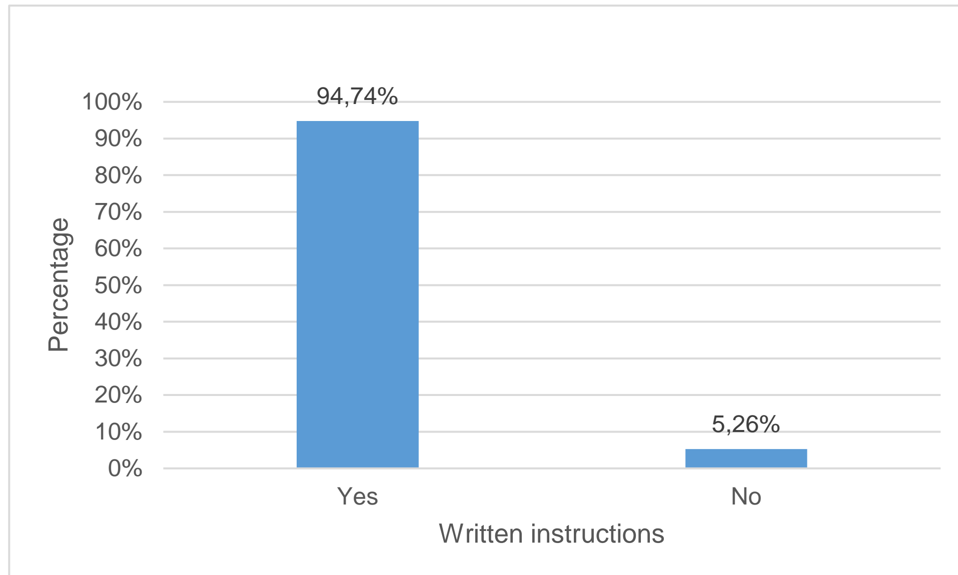

Figure 10: Written instructions by dentists (N=114)

4.4.6 Drawing or design by dentists

None of the dentists supplied a RPD design or drawing to the laboratory.

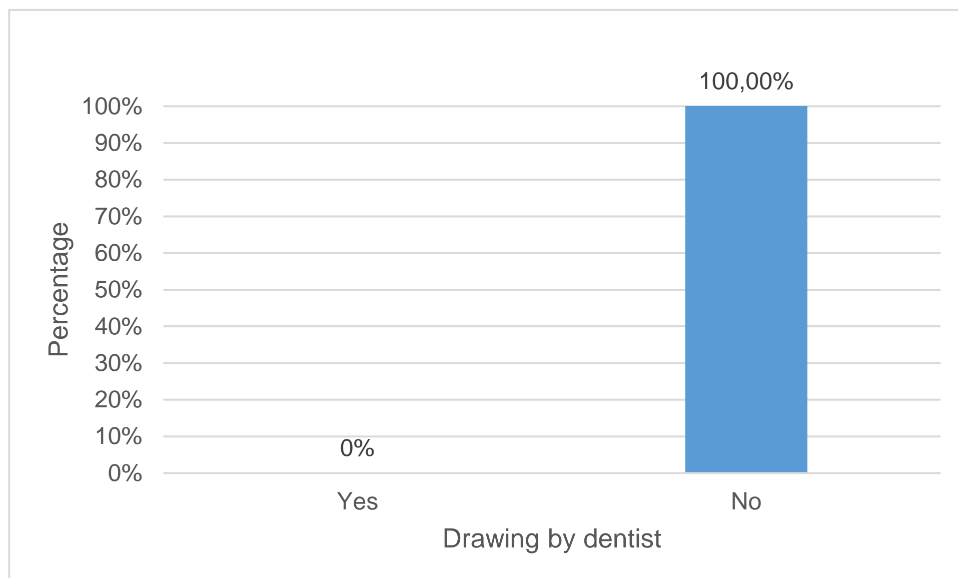

Figure 11: RPD Drawing by dentist

4.4.7 Drawing or design by dental technician

None of the dental technicians created a drawing of the RPD design.

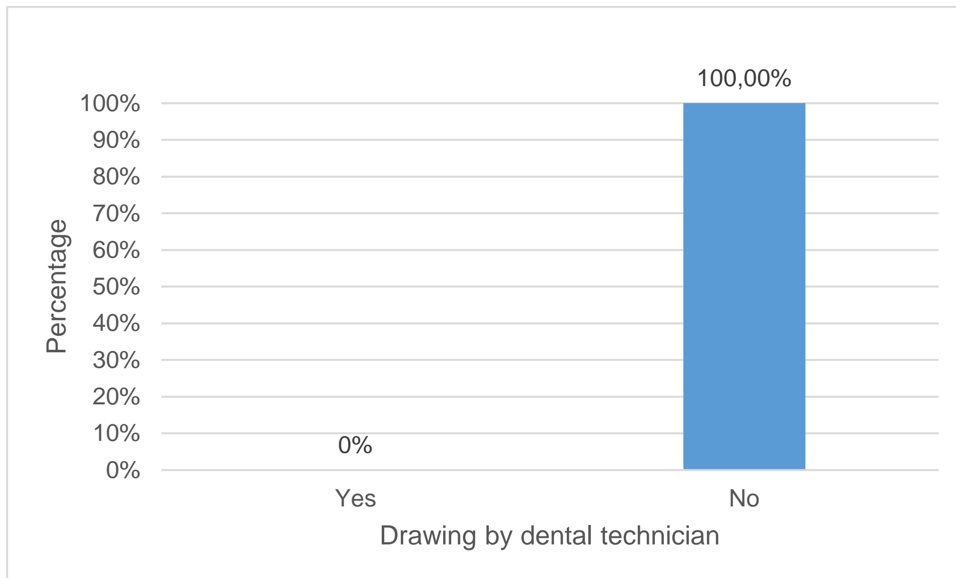

Figure 12: Drawing by dental technician

4.4.8 Presence of rests

The presence of rests was reported in 21.93% of the dentures as shown in Figure 13.

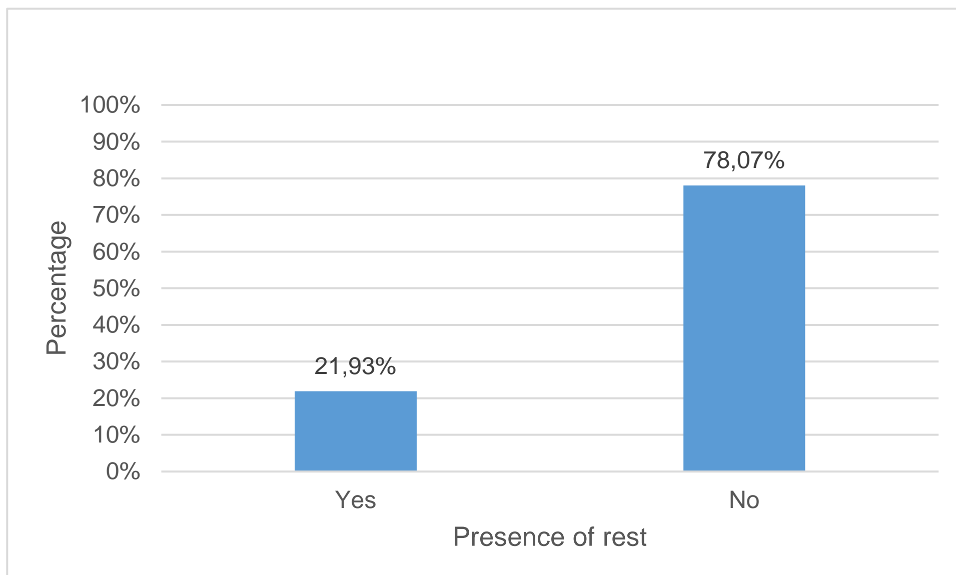

Figure 13: Presence of rests

The median number (interquartile range) of rests reported was 2 (2) in all the removable partial dentures where the presence of one or more rests was reported.

4.4.8.1. Number of rests in acrylic-based vs metal-based RPD's

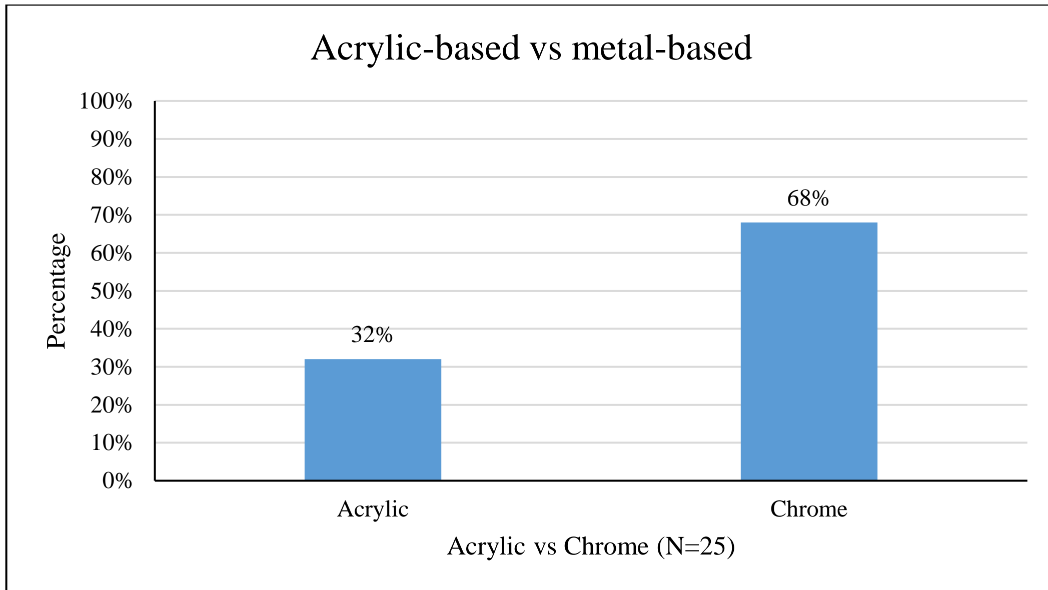

Figure 14: Presence of rests in acrylic-based vs metal-based RPD's

4.4.9 Presence of prepared rest seats

The presence of prepared rest seats was reported in only 3.51% of all the dentures (Figure 11)

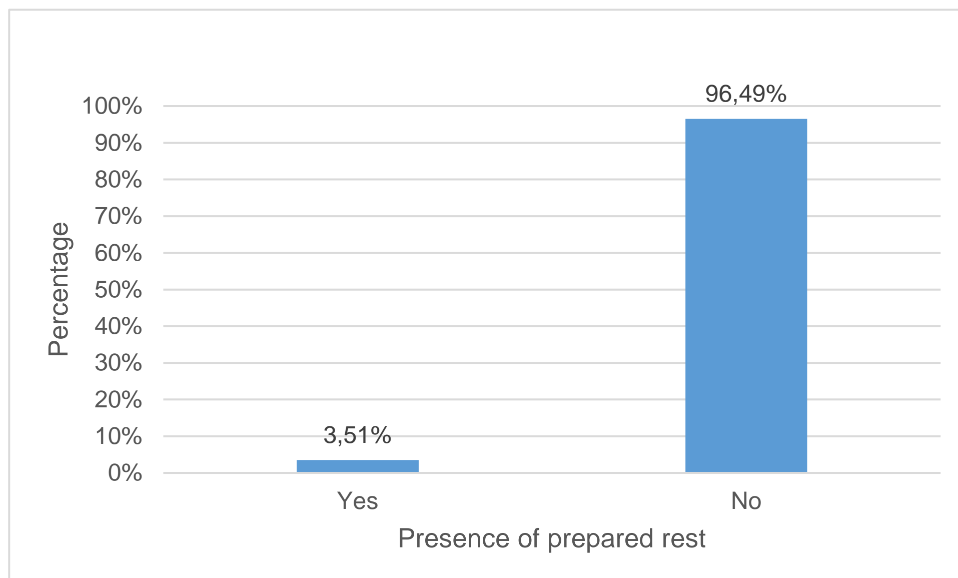

Figure 15: Presence of prepared rest seats (N=114)

The median number of prepared rest seats reported was 2.5 (1.5- 4) in all the RPD's where the presence of a prepared rest seat was reported.

4.4.10 Presence of clasps

The presence of clasps was reported in 47.37% of the dentures.

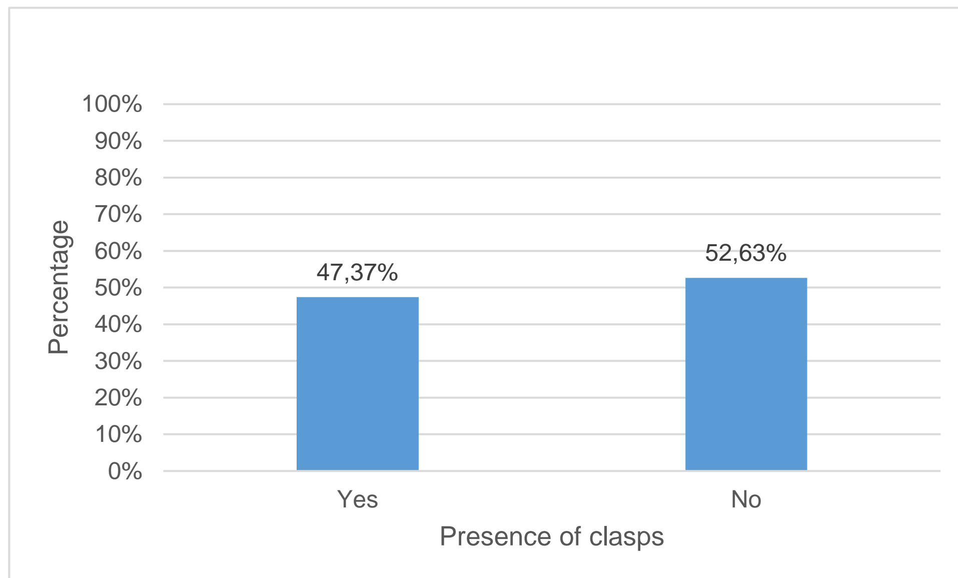

Figure 16: Presence of clasps (N=114)

The median number of clasps reported was 2 (2-2) in all the dentures where presence of clasps was reported.

4.4.11 Presence of guide planes on the master cast.

None of the master casts had guide planes present

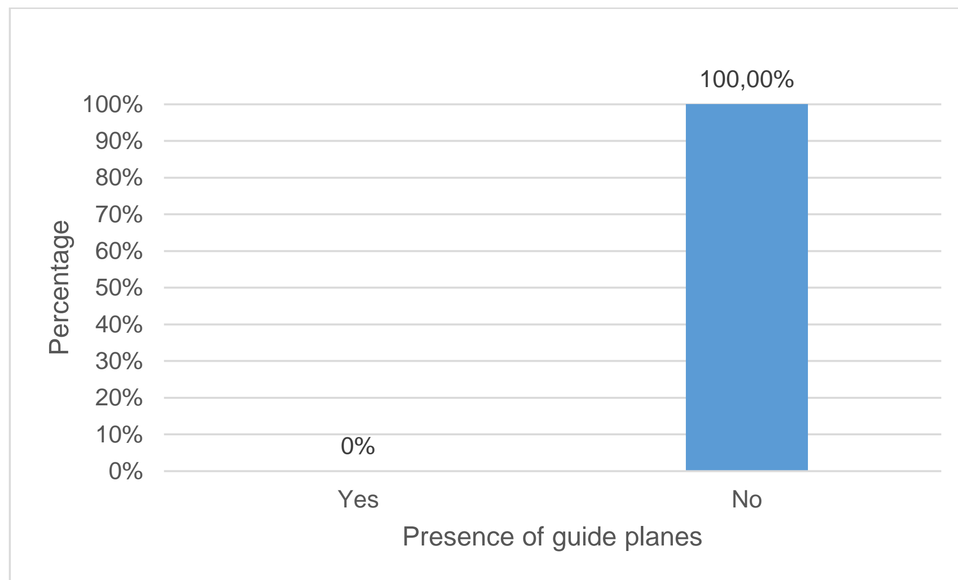

Figure 17: Presence of guide planes on master cast

4.5 Comparison of public and private sector RPD designs

4.5.1 Association between type of denture base and practice sector

The Chi-squared test was used to determine the association between the type of denture used and practice (public vs. private) as shown in Table 1.

Table 1: Association between type of RPD base and practice sector

Type of denture	Public, n	Private, n	Chi-Square	P-value
Acrylic	35	60	10.10	0.001
Chrome	0	19		

The result showed that there was a significant association between the type of practice and choice of denture used (X^2 = 10.10, p = 0.001). Binary logistic regression was used to

determine the direction of the association and the results showed that practice was not a significant predictor of the type of denture used, Exp (B) = 0, p-value = 0.998.

The sector is not a determinant of the type of denture, the association was a random association and it is not a predictor of the type of denture used. Although the public sector in this report did not prescribe cobalt chromium bases, and only 31.6% of the private sector used metal bases.

4.5.2 Association between site of denture and practice sector

The Chi-squared test was used to determine the association between the anatomical site of denture used and practice (public vs private) as shown in Table 2.

Table 2: Association between site of denture and type of practice

Site of denture	Public, n	Private, n	Chi-Square	P-value
Lower (Mandibular)	15	28	0.57	0.45
Upper-Maxillary	20	51		

The result showed that there was no significant association between practice and site of denture used ($X^2 = 0.57$, $p = 0.45$).

4.5.3 Association between standard designs and type of practice

Table 3 presents the results of the association between standard designs and practice (public vs private).

Table 3: Association between standard designs and practice

Site of denture	**Public n**	**Private, n**	**Chi-Square**	**P-value**
Surveying models by dentists				

Yes	0	1	0.45	0.5
No	35	78		
Surveying models by dental technicians				
Yes	0	0		
No	35	79		
Presence of articulated diagnostic casts				
yes	0	0		
no	35	79		
Verbal instructions				
Yes	2	1	1.87	0.17
No	78	1		
Written instructions				
Yes	33	75	0.021	0.89
No	2	4		
Drawing by dentist				
Yes	0	0	-	-
No	35	79		
Drawing by dental technician				
Yes	0	0	-	-
No	35	79		
Presence of rest				
Yes	3	22	5.26	0.02*
No	32	57		

Presence of prepared rest seat				
Yes	1	3	0.06	0.8
No	34	76		
Presence of clasps				
Yes	14	40	1.1	0.29
No	21	39		
Presence of guide planes on the master cast				
Yes	0	0		
No	35	79		

The result showed that only the presence of rests had a significant association with the type of practice ($X^2 = 5.26$, p-value = 0.02). Binary logistic regression was further used to determine the direction of the association; and the results showed that practice type was a significant predictor of the presence of rests. The private sector for this analysis was considered the standard (reference) because they recorded a relatively higher presence of rests.

4.5.4. Association between type of denture and practice sector in dentures that had rest placement

Using Fischer's exact test, there was a statistically significant association between the type of RPD base and practice sector in patients that had rests, p=0.024. Presently the public sector in Ekurhuleni does not fabricate chrome cobalt RPDs.

Table 4: Association between type of denture and practice sector in patients that had rest placement (n=25)

	Public	**Private**	**p-value**
Acrylic	3(100%)	5(22.7%)	0.024
Chrome	0(0)	17(77.3%)	

4.5.5. Association between specifications of teeth to be replaced and practice sector

Using Fischer's exact test, there was a statistically significant association between teeth to replace and practice sector p=0.000

Table 5: association between specifications of teeth to be replaced and practice sector

Specifications of teeth to replace	Public	Private	p-value
Yes	0(0)	35(100)	0.00
No	79(100)	0(0)	

4.5.5. Association between request for clasps and practice sector

Table 6: association between request for clasps and practice sector

Request for Clasps	**Public**	**Private**	**p-value**
Yes	2(5.7)	8(10.1)	0.355
No	33(94.3)	71(89.9)	

Table 7: Binary logistic regression

Presence of rests	Sig.	Exp(B)	95% C.I.for EXP(B)	
			Lower	Upper
Public	0.03	0.243	0.067	0.875
Private	Reference	Reference	Reference	Reference

Dentures prescribed by clinicians from the public sector are 76% less (OR=0.24) likely to have rests present when compared to those prescribed by the private sector, Exp (B) = 0.24, p-value = 0.03) as shown in Table 4.

5. DISCUSSION

Removable partial dentures (RPDs) are a viable and cost effective treatment option that can improve the oral-health related quality of life of partially dentate patients, particularly in developing countries (Farias-Neto et al, 2011), as well as in developed countries (Ozhayat & Godfredsen, 2013). In a South African study, patients reported an improved function, satisfaction and oral health-related quality of life after prosthetic treatment with RPDs (Khan et al, 2019).

Rehabilitation of the partially dentate patient requires the clinician to be cognisant of mechanical and biological factors. A biologically acceptable design incorporates factors such as the periodontal condition, number and status of remaining teeth, the nature of the opposing teeth (artificial vs natural), hygienic principles and aesthetics. An ideal RPD is customised for the patient, integrating the clinical findings into a design that widely distributes the occlusal load to include tooth and mucosal support, preferably with the teeth providing more of the support. Retentive elements including active retention (e.g. clasps) and passive retention (guide planes) contribute to the overall retention and stability of the RPD. Eliminating redundant components and covering excessive mucosa is avoided, and in so doing optimal hygienic principles are incorporated into the RPD and the design is thus simplified (Campbell at al, 2017).

Factors contributing to the success or failure of RPDs are biological, mechanical, and patient factors such as perception, oral and denture hygiene practices and habits. Design factors also contribute in that (Allen, 2010; De Kok et al, 2017). Designing RPDs may be challenging and available design guidelines do not offer guidance for every possible edentulism combination. Furthermore, as many as 243 possible errors during RPD fabrication can contribute to clinical complications (Rudd & Rudd, 2001).

Failure of RPDs related to poor retention, stability, occlusal deflective contacts and patient reported discomfort has been documented (Wetherell & Smales, 1980). Complications associated with RPDs are mainly related to inadequate quality, lack of biomechanically sound and hygienic design principles (Owall et al, 2002). Poor RPD designs exacerbate plaque accumulation, and iatrogenic damage to hard and soft tissue, resulting in RPDs being associated with caries and periodontal disease (Wostmann et al, 2005; Wright & Hayller 1995). Lower failure rates have been observed when the emphasis on biologically acceptable

designs, regular maintenance visits and oral hygiene education was reinforced (Bergman et al, 1982; Chandler & Brudvik, 1984).

This study evaluated the design of removable partial dentures fabricated within three dental laboratories serving the private and public sectors, in Ekurhuleni, South Africa. This enabled the researcher to identify common practices that dentists and dental technicians undertook in RPD design.

An assessment of technical quality of the dentures prescribed in the public and private sector revealed the following:

5.1 Frequency of denture prescriptions sent by dentists to the laboratory technicians

Communication between dentists and technicians has been reported to occur primarily through using standard laboratory authorisation forms (Tulbah et al, 2017). These authorisation forms are meant to clearly indicate the design of the prescribed denture thus design information must be clearly written, comprehensive, and preferably accompanied by a design drawing with specifications (as is commonly taught during university training) . Tulbah et al (2017) reported that only 46% of laboratory technicians indicated prescriptions were completed accurately.

This study population included 114 RPD prescriptions received by three dental laboratories. All RPD requests were prescribed on a generic laboratory form, provided by the respective laboratories. Denture prescriptions were photographed by the dental technicians. Despite denture 'prescriptions' being sent to the laboratory, all of the prescriptions were inadequate. The most common information included in the prescriptions was specifying the teeth that were required to be replaced, which was found in 30.7% of the prescriptions. Interestingly, only dentists from the private sector had included this specification. The laboratories in this study charge per number of teeth being replaced, thus dentists from the private sector may be more proactive in providing this information due to cost implications. Some prescriptions included requests for clasps to be placed (8.77%), but none of them had specified the teeth to be clasped, type of clasp and material, undercuts and wire diameters to be used. RPD design drawings were not submitted with any of the laboratory forms.

None of the dentists had specifically requested rests to be included in the design and the decision for their placement was entirely left to the technician's discretion. Similar findings

were observed in a previously conducted survey, which reported that more than 80% of dentists communicated through generic laboratory scripts only, with 89.5% rarely or never giving additional details regarding RDP design (Haj-Ali et al, 2012). Farias-Neto et al (2011) reported fifty-one percent of RPD casts were submitted to laboratories without specifying the design or providing written instructions.

In a survey conducted by Taylor et al (1984), more than 88% of dental laboratories reported that the dentist's communication to them was lacking. The study also reported that the majority (77.9%) of RPDs were designed by the technicians and not the dentists. The reasons for this are unclear. Taylor et al (1984) suggested lack of confidence amongst dentists in knowledge of RPD design and an unwillingness to spend extra time to design the dentures as possible reasons for this poor communication. Lynch & Allen (2003) reported that only 10% of written instructions included details on retention, support and connector design, thus highlighting the poor quality of written instructions.

Dentists supported the view that success would be positively influenced if they designed the RPD, however, only 46% of dentists claimed to design their own RPDs in practice, due to time constraints (Allen, 2010). This highlights the divergence between knowledge and what is practiced clinically (Allen, 2010).

Mandatory comprehensive completion of laboratory work authorisation forms by dental clinicians is required, prior to RPD fabrication in the United States. The laboratory script is considered a legal document, and is duplicated and included in patient records (Bohenkamp, 2014). Similar legal and ethical guidelines have been included in Medical Devices Directive (European Union) and the British Society for the Study of Prosthetic Dentistry (Haj-ali et al, 2012). The clinician has the best knowledge of the clinical situation and thus it is the responsibility of him/her to design the RPD. To the author's knowledge, such guidelines have not been published in South Africa.

The design of an RPD should be approached systematically, taking into account the patient-specific factors, such as periodontal health, the condition of opposing teeth, the length of the edentulous span and aesthetics.

High failure rates in RPDs occur due to lack of planning, leading to mucosal inflammation, ulceration and development of periodontal pockets, increased tooth mobility and ultimately loss of abutment teeth has been reported (Miyamoto et al, 2007; Tada et al, 2013).

5.2 Type of denture

In this study, acrylic dentures were the more common type of RPD prescribed, at 83.3% while 16.67% were metal-based. Public dental clinics in Ekurhuleni district were only able to offer acrylic dentures largely due to budget constraints on laboratory expenditure. It is unclear as to why dentists in private sectors offer mainly acrylic-based RPDs. All of the laboratories in this study subcontracted the fabrication of metal-based RPDs to other laboratories. All three laboratories included in this study reported fabricating metal frameworks in-house was not financially viable, as the specialised machinery required is expensive. Furthermore, given that the frequency of dentists prescribing metal-based RPDs is much less than acrylic RPDs, this additional investment in equipment could not be justified in their respective laboratories. This outsourcing of metal-based RPDs might be further increasing the cost, accounting for the scarcity in prescribing it.

Lynch & Allen (2003) reported only 16% of laboratories in Ireland have the facilities to fabricate metal-based RPDs. Acrylic RPDs are a cost effective solution for immediate aesthetic restorations, teeth with a questionable long term prognosis, and are often prescribed as an interim prosthesis prior to implant placement and fixed restorations, as well as in patients who are too young or unwilling to receive advanced prosthetic treatment at their age (Graham et al, 2006). Despite no data being available with regards to the material of choice for RPDs in South Africa, Wilson (2009) postulated that the number of acrylic-based RPDs outnumbered metal-based RPDs, because of the low socio-economic status of the population at large.

Allen (2010) reported similar results, as 75% of RPDs constructed were acrylic-based. The decision to prescribe acrylic-based RPDs was mainly driven by cost implications. Furthermore, the study reported that medical aid schemes only subsidised the costs incurred in fabricating acrylic RPDs, whereas metal-based RPDs were not subsidised. Thus metal-based RPDs were less frequently prescribed. Dentists working in the public sector in the United Kingdom and Ireland are contracted to provide care under National Health Services (NHS) guidelines. The NHS pays dentists a sum for fabricating the RPDs, from which technician costs are deducted. Dentists reported that metal-based RPDs required more clinical time. As such, fee structures devised by NHS were not feasible and proved a disincentive to fabricating metal-based RPDs (Graham et al, 2006; Allen, 2010).

5.3 Site of denture placement

In both the private and public sectors, maxillary dentures were the more commonly fabricated RPDs (62.26%) compared to mandibular RPDs (37.2%). Similar findings were reported by Farias-Neto et al (2012), as maxillary RPDs accounted for 60% of the study sample.

Patient attitudes towards aesthetics is a major contributor in influencing the success of treatment, more so in the maxillary arch. Maxillary anterior tooth loss affects social interactions and self-esteem (Allen, 2010). This may provide a reason why maxillary dentures are generally more frequently prescribed.

Allen (2010) reported that dentists in his study observed a greater failure rate with mandibular RPDs, and preferred prescribing fixed treatment options or opting for maintenance of a shortened dental arch. This may explain the reduced number of mandibular RPDs prescribed. The findings in the literature and in this study suggest that mandibular dentures may not be fabricated as often due to financial constraints, perceived lack of need by patients and the choice to preserve a shortened dental arch as a treatment option, rather than introducing an often bulky acrylic denture to replace a few teeth in an otherwise functional occlusion (Graham et al, 2006; Teofilo and Leles, 2007).

5.4. Articulated diagnostic casts

Articulated diagnostic casts translate the maxillo-mandibular relationship onto an articulator, providing the clinician and technician an opportunity to accurately plan the RPD design and occlusal adjustments. The stone casts provide an accurate relationship of the hard and soft tissues (Bates, 1978). Articulated diagnostic casts allow evaluation of interarch space, premature occlusal contacts, working and balancing interferences and an overall evaluation of the occlusal scheme that may otherwise be overlooked clinically or impossible to see clinically (eg, lingual contacts of teeth in occlusion on diagnostic casts). Denture components such as rest seats that may interfere with the occlusal scheme, opposing tooth enameloplasty and indirect abutment restorations are planned for (Beaumont, 2002).

In this study, none of the diagnostic casts had been articulated, suggesting a lack of planning prior to tooth modification (if any took place) and denture design. Occlusal modification may be carried out in haste, without consideration for biological cost, for example at delivery if occlusal interferences are present.

5.5 Surveying of models by dentists and technicians

Surveying enables clinicians and technicians to plan for the establishment of a path of insertion, and identification of soft and hard tissue undercuts thus eliminating interferences during RPD fabrication.

The inclination of the models is adjusted in order to obtain the best possible path of insertion, with optimal guide planes and retentive elements of the prosthesis. By changing the path of insertion, planning enamel re-contouring and restorations, as well as guiding surface extensions, one can then increase the retentive force of the prosthesis (Dastevski et al, 2018).

By omitting surveying, areas of soft tissue undercuts that need to be blocked out may not be identified, resulting in acrylic entering the undercut area, preventing denture placement. Attempting to make the RPD seat results in the dentist removing acrylic around the teeth, translating to a loss of reciprocation provided by the acrylic. Guide planes and the extent and position of undercuts on teeth to be clasped cannot be planned for accurately without surveying the models (Owen, 2018). In order to achieve predictable outcomes, the prosthesis must be carefully planned, designed and fabricated (Arafi & Habar, 2017). The fundamental principle of this is dental surveying or parallelometry, which enables hard and soft tissues to be analysed accurately (Dastevski et al, 2018).

In this study, only one dentist had surveyed a patient's casts, in a single case. There was no evidence of planning or preparation having been carried out on any other primary casts by technicians and dentists alike. It could be concluded that only one of the primary casts was used in diagnosis and treatment planning.

Except for the one case, the primary casts were used solely for fabrication of a special tray. In some instances, dentists did not even record a secondary impression and requested the RPDs to be fabricated using the primary casts, on which neither tooth preparations nor modifications were present. Diagnostic casts were not articulated in any of the cases. The reason behind this may stem from clinicians not deeming surveying necessary, or having clinical time constraints, or resisting the cost of purchasing a surveyor and additional materials (and laboratory steps) utilised for articulating casts and secondary impression recording.

From the author's personal experience within the public sector in Ekurhuleni, none of the clinics within the district had a dental surveyor. Similar trends may be observed in individual private clinics. If clinicians within the private sector possessed dental surveyors, they were likely not routinely utilised. Leeper (1979) suggested that dentists may be underestimating the importance of the use of a dental surveyor in RPD design. Furthermore, there is a belief by dentists, that the technician has more experience and dentists elect to delegate this responsibility to them (Farias-Neto et al, 2012). Delegating surveying and design of the denture to the technician is unethical, as the diagnosis, prognosis and treatment planning are the responsibility of the dentist (Farias-Neto et al, 2012).

5.6 Verbal and written instructions from dentists

Within this study, verbal instructions from dentist to technician were reported in only 2.63% of cases. Verbal instructions may not be ideal as they are prone to misinterpretation, misinformation or omission of details and they do not leave a physical trail (Bin-Shuwaish, 2017). Written instructions are proven to be superior and can serve as a medico-legally protective document for the clinician and technician.

The majority of dentists had submitted written instructions, however, the quality of these instructions were lacking in detail and the design was completely left to the discretion of the dental technicians. Overall, clinicians had poor communication with the laboratory, both in verbal and written form. This resulted in the absence of, or inadequate denture designs that would potentially lead to the production of low quality dentures. Examples of instructions provided by clinicians to technicians are presented in Figures 16 and 17 in the appendix.

Similar results had been reported in another study, with only 30% of written instructions being clear (Kilfeather et al, 2009). The overwhelming consensus in the literature is that communication between dentists and dental technicians continues to be poor (Pun et al, 2011; Rice el al, 2011, Tulbah et al, 2017).

The fabrication of a high quality biologically sound prosthesis requires the skills of both the dental practitioner and technician. Inadequate communication of design information may result in a prosthesis that has little reference to the clinical and radiographical aspects of diagnosis, resulting in fabricating a denture that is potentially harmful to hard and soft tissues (Owall et al, 2002).

Christensen (2009) made suggestions in terms of unifying and improving dentist-technician communication to ensure the desired outcome is achieved. These include:

- Continuing professional development courses for dentists that may include dental technicians, especially in sessions aimed at improving RPD design. This would enhance knowledge of various clinical and laboratory procedures for both professionals.
- The dentist and the dental technician should discuss RPD design including alternative designs, ensuring the patient receives the best possible care.
- Discussions could be via electronic communication including e-mails with photographs and/or online meetings. Complex cases may be discussed prior to design to gain the technical and clinical input from both parties.
- Increased quality and scope of communication on laboratory prescription forms. The generic laboratory forms are A5 sized and do not have a designated area to include teeth to be clasped, presence of rest seats, materials used, major connector design and undercuts to be engaged by the clasp, nor an area for RPD designs. Laboratory forms should include this information, encouraging dentists to complete the form thoroughly.
- Incorporating dental technicians into dental practices/ buildings to enable easier access and to eliminate communication barriers.
- Promoting the integration of undergraduate education for dentists and technicians.

5.7 Design drawings by dentists and technicians

None of the dentists (0%) had submitted any form of drawing illustrating the design specifications required, nor had any of the technicians designed RPDs in a diagrammatic format prior to fabrication, or discussed design planning with the dentists. The importance of denture design has been emphasized in the literature (Potter et al, 1967; Owall et al, 2002). Similar trends have been reported in other studies where the RPD design is largely delegated to dental technicians (Basker and Davenport, 1978).

Pun et al, (2011) concluded that there is no evidence to show that an optimally constructed RPD, which has been well-maintained, contributes to periodontal disease. This further highlights that by adhering to sound RPD design principles and fabrication practices, clinicians may be able to reduce common problems associated with RPDs.

5.8 Presence of rests

RPDs have the advantage of being tooth and mucosal supported. Tooth support wherever possible is preferred, as the teeth are able to withstand larger forces than the easily displaceable mucosa (Owen, 2018). An RPD that does not incorporate rests for tooth support, directs the forces applied by the denture tissue-ward, resulting in a denture design commonly described as a ‘gum stripper’ (Owen, 2018) as the mucosa recedes away from the gingival margins of teeth due to the majority of forces during function being directed towards the soft tissues more than the teeth. Figures 19, 20 and 21 in the appendix are examples of RPDs fabricated without rests. Accurately fabricated rests minimise iatrogenic soft tissue damage by directing occlusal forces along the long axis of the tooth, such that less forces are directed tissue-ward. In this study, rests were placed in only 21.93% of the dentures. In this study, metal-based RPD’s incorporated 68% of the rests, thus explaining the reason why the private sector fared better than the public sector in relation to placement of rests. This is most likely related to the metal framework fabrication process, as rests are incorporated and casted simultaneously as part of the framework. When comparing acrylic-based RPD’s and rests between private and public sector, no statistically significant association could be drawn, given the small number of acrylic-based cases that had rests incorporated in both sectors.

The clinical consequences of this finding is that the soft tissues are at risk due to occlusal forces being directed tissue-ward and the support of the RPDs is compromised.

Farao & Geerts (2020) in a South African study reported a similar lack of vertical support amongst acrylic-based RPDs designs, as only 1 acrylic-based RPD had sufficient rests of an appropriate configuration to provide adequate tooth support. The metal-based RPDs complied better in terms of support provided, as 45% provided acceptable vertical support.

5.9 Presence of prepared rest seats

Occlusal and incisal rest seats are prepared on the occlusal (mesial and distal) surfaces of molars and premolars and cingulum rest seats on lingual surfaces of anterior teeth to accommodate rest components of a partial denture so that occlusal forces can be directed along the long axis of the tooth, thus providing tooth support to the RPD (Owen, 2018; Stilwell, 2010).

Rest seats were prepared in only 3.51% of RPDs, despite rests being present in 21.93%. Whilst none of the laboratory scripts specifically requested rests, they seemed to have been provided for randomly by technicians. Each dental laboratory had at least two or more dental technicians present daily. It is the opinion of the author that the possible discrepancy between rest provision stems from the technician's individual preference for providing rests in particular cases.

Rice et al (2011) found that even when rests were requested by the practitioner, only 30% had prepared rest seats on the teeth and were visible on the master cast. Of these many were either over or under prepared, and inter-occlusal clearance was inadequate (Rice et al, 2011). This study also highlighted the rarity of rests being requested by dentists, clearly indicating poor planning during treatment. Farai-Neto et al (2011) reported that of the clinicians that specifically requested occlusal and cingulum rests, only 30% of the master casts displayed evidence of rest seat preparation.

A study conducted in the United Arab Emirates reported slightly better results. Haj-Ali (2012) reported that 68.4% of casts prepared for RPD designs had rest seats present, however no other tooth modifications were carried out. Preparation of guide planes, path of insertion establishment (surveying), undercuts, modifications for reciprocation, were all neglected by dentists and technicians. Similar results were reported in another study where 20% of RPDs lacked rest seats (Pun et al, 2011). In the same study it was reported that only 23% of acrylic-based RPDs had rests (Pun et al, 2011).

5.10 Presence of clasps

Clasps provide active retention against dislodgement of the denture during function. RPDs that are poorly designed result in insufficient retention and subsequently, patient dissatisfaction and treatment failure. Clasps were more frequently placed, compared to other RPD components evaluated in this study. This may be due to patients being able to perceive better retention than when clasps were not placed (Alageel, 2019).

Results from this study showed that, 47.37% of dentures had clasps present. This percentage was higher as compared to all other parameters evaluated in this study. All three laboratories reported the use of Remanium Hard wire (Chromium nickel stainless steel alloy) as the material of choice for making clasps for acrylic-based partial dentures, with diameters ranging from 0.7mm to 1.0mm, for premolars and molars respectively. The decision on which clasp diameter to use was, however, left to the discretion of the technicians. Metal-based RPDs would either

have a Remanium Hard clasp soldered onto it, or a cast clap attached to the major connector via a minor connector, or a combination thereof. This too was based on what the technician deemed ‘fit’ or appropriate for use in that instance.

Since dental surveyors were not routinely used, undercut locations and depth measurements were omitted, and technicians would have to estimate the placement of clasps and depths of undercut purely by visualisation. For acrylic dentures that incorporated C-clasps, the denture base acted as a reciprocal element, and preformed ball clasps were incorporated for active retention. Ball clasps, although lacking in flexibility, were advantageous when used as they served concurrently as a rest as they passed over the embrasure occlusally. This advantage however, may not prove to serve its intended use if the undercuts between the two teeth where it is placed are not engaged properly (Owen, 2018). Visual examination is inaccurate in locating and measuring undercuts. A dental surveyor is necessary to locate the undercut that retentive clasp arms will occupy. Use of larger undercuts or insufficient undercuts results in unretentive RPDs, excess force on abutment teeth and deformed clasps (Farias-Neto et al, 2012). The wrong combination of clasp diameter or type and undercut size can lead to failure of the clasp (Owen, 2018).

In metal-based RPDs, cast clasps should ideally not be placed on premolars. This is because premolars have an insufficient mesiodistal width to prevent fatigue and fracture of the stiff clasp. For example, the modulus of elasticity of cast cobalt chromium is higher compared to gold or stainless steel wire, making it a material of greater stiffness. As clasps require being able to flex in and out of the tooth undercut repeatedly without being deformed, a cast clasp on a premolar will not have sufficient length and is therefore more likely to deform or fracture (Owen, 2018). When cast clasps are placed on molars, they should engage 0.25mm undercuts for optimum use (Owen, 2018). Since undercuts were not measured in all the cases in this study, it is unlikely these guidelines were adhered to and incorrect combinations of clasps and undercuts were likely to occur.

Studies have found RPDs that had clasps placed had increased gingival inflammation, particularly below clasp arms (Dula et al, 2015; Chandler et al, 1984). Clasp placement may sometimes be unnecessary, if sufficient guide planes on the teeth and guiding surfaces on the denture are present or created (Owen, 2018).

5.11 Guide planes

Guide planes are flat surfaces in a corono-gingival direction on abutment teeth and they are prepared parallel to one another and to the path of insertion (Bezzon et al, 1997). They provide a path of insertion and removal, reducing stresses on abutment teeth and restorations. Guide surfaces are present on the denture as the counterpart of the guide planes (Mothopi-Peri & Owen, 2018). Guide planes of adequate length aid in reciprocation and passive retention of the denture (Stern, 1975). Proximal guide planes aid in stability of the prosthesis, whilst reciprocal guide planes control forces exerted by the retentive arm. Designs of these planes can be done by surveying the diagnostic casts (Lee et al, 2019). They may also be created to provide reciprocation for clasps (Owen, 2018).

No guide plane placement was reported in any of the RPDs fabricated in this study, or in the photographic images that the researcher had access to, and their presence could not be verified otherwise. Prior to accurate guide plane placement, the path of insertion should have been established after surveying the diagnostic casts, but only 0.88% of the casts had been surveyed.

Guide planes parallel to the chosen path of insertion can then be appropriately placed (Canning and O' Sullivan, 2008). With no clear evidence of surveying by dentists and technicians, it can be concluded that the guide planes were neither planned for nor placed. Schwarz & Barsby (1980) reported only 6% of general dentists prepared guide planes frequently.

Intimate contact between guiding planes on abutment teeth and the guiding surfaces of the RPD resulted in an increase in retention, as reported by Mothopi-Peri & Owen (2018). The study suggested omitting clasps when 6 or more guide planes are present, in that the latter would provide sufficient passive retention, depending on the distribution of the guide planes in the arch.

5.12 Association between type of denture and practice.

When design principles were compared between the private and public sector, none of the comparisons were statistically significant with the exception of the presence of rests. The results illustrated that dentures produced in the private sector were 76% more likely to include rests, compared to the public sector. This is due to all (100%) of the metal-based RPDs being fabricated in the private sector. As metal-based RPD's accounted for 68% of the total number of rests provided, the private sector fared better than the public sector in relation to placement of rests. This is most likely related to the metal framework fabrication process, as rests are incorporated and casted simultaneously as part of the framework.

Dentists in the public sector only prescribed acrylic RPDs. When comparing acrylic-based RPD's and rests between private and public sector, no statistically significant association could be drawn, given the small number of acrylic-based cases that had rests incorporated in both sectors.

5.13 Continuing education

A study conducted at a UK dental school found that undergraduate studies were not always sufficient in preparing clinicians for RPD design principles, and teachers of RPD design principles were found to lack confidence, had no clear guidelines and protocols in place, and thus could not reach a consensus of opinion when designing RPDs (Johnson and Wildgoose, 2010).

Whether the prescriptions were from private or public practices in the UK, almost 50% of dentures were constructed without instructions from the clinician to the laboratory for the design and fabrication of cast dentures. Criticism was generally directed towards public health services implying that if the fee was increased, the quality of the service would in turn increase. Findings from this study, however, found no significant differences between practices employed by public and private health systems (Lynch and Allen, 2006). It may be that dentists find partial denture principles challenging due to a lack of educational experience or that the education received from undergraduate training may have been forgotten (Schwarz and Barsby, 1980; Basker et al, 1988; Lynch and Allen, 2006).

Culwick et al (2000) reported that the size and shape of occlusal rest seats prepared by university staff and postgraduate students demonstrated superior quality than those prepared

by general dentists in the non-academic public and private sector. This study sheds light on the need for a ‘refresher’ course in the clinical practice of tooth modification during RPD design and construction.

The Gauteng district, which includes Ekurhuleni, conducts a compulsory, free continuing education programme for dentists in its employment. The district has thus identified a need for calibration of dentists to encourage higher standards of care. The findings of this study support this identified need for more continuing education, especially on partial denture techniques and design methods to the public and private sector dentists and technicians.

Trainor et al (1972) demonstrated that additional training in RPD design for postgraduates significantly assisted practising dentists to gain confidence and proficiency in communicating detailed and adequate prescriptions to their respective dental laboratories.

5.14 RPD design principles and the provision of effective RPDs

There is no universal set of design principles prescribed for RPDs that are comfortable to use and maintain the health of the remaining hard and soft tissues. This study investigated design principles that are recommended in the design and fabrication of RPDs in the literature (Rudd and O Leary, 1966; Runov et al., 1980; Boucher and Renner, 1982; Rudd et al, 1983; Chandler and Brudvik, 1984; Jacobson, 1987; Stratton and Wiebelt, 1988; Bergman and Ericson, 1989; Grasso and Miller, 1991; Becker et al, 1994; Witter et al, 1994; Academy of Prosthodontics, 1995; Davenport et al, 1996; Carr AB et al, 2005 ; Sarita et al, 2003; Dunham et al, 2006; Jones and Garcia, 2009; Koyama et al, 2010; Stilwell, 2010; Mothopi-Peri and Owen, 2018; Owen, 2018). These included the articulation and surveying of diagnostic casts, the provision of an RPD design that included sufficient tooth support, and adequate retention prescribing the clasp and undercut depth, the preparation of rest seats for force distribution, and the use of guide planes for passive retention.

The dentist has knowledge of the biological factors and the influence of mechanical factors of RPDs on the remaining hard and soft tissues. In addition, the dentist would have undertaken a clinical examination, evaluating the oral environment, and the patients’ medical and dental history. Therefore, the dentist would be able to integrate and interpret those aspects that are significant in successful RPD treatment. Furthermore, anticipated future oral changes such as future tooth loss can be taken into account when designing the RPD. Ultimately, a design that enhances rather than compromises oral function can be fabricated.

Unfortunately, this study revealed that dentists do not provide this information and allow dental technicians who do not have the same clinical insights, to design the RPD, risking omitting design features that improve the success of the RPD treatment.

6. CONCLUSION

The available literature reported an association between knowledge and denture service quality. Therefore, it remains necessary to provide undergraduate students with adequate training and experience, as well as postgraduate refresher courses in basic design principles.

Within the limitations of this study, it can be concluded that few clinicians and technicians adhere to principles of partial denture design, even though these are extensively taught and adequately practised during undergraduate training.

This may be due to:

1. Clinicians deem these procedures unnecessary, not economically viable and time consuming.
2. Understanding of the design principles and their importance in RPD construction may be lacking, under-utilised and ultimately disregarded during general dental practice.
3. Clinicians deem a procedure necessary based only on the result of patient satisfaction and not on satisfying biological principles (Schwarz and Basrby, 1980).
4. Surveying which informs all other principles is ignored. This results in all necessary modifications not being accurately carried out, or not conducted at all, leading to production of poorly designed partial dentures that cause iatrogenic damage.
5. Clinicians lack confidence in the practice of denture design, and avoid carrying it out. With prolonged avoidance, the principles are forgotten.
6. Technicians who are accustomed to habitually taking the sole responsibility of designing for clinicians may fear implementing ‘new’ changes and not adhere to a prescribed denture design. It has been found that 94.7% of dental technicians feel that dentists should depend on technicians for denture design decisions (Haj-Ali 2012).

In this study, there were no significant differences between technical quality of RPDs produced in the private and public sectors. RPDs were neither designed nor constructed to satisfy the principles of partial denture design. This may be interpreted that the provision of partial dentures is not based on sound evidence-based practice in either the private or public sector, even though there is a general perception that patient service in the private sector is superior and provides better quality than the public sector.

7. RECOMMENDATIONS

- Successful RPDs comply with biomechanical aspects of support, retention and stability, whilst preserving intra-oral hard and soft tissues (Faroa & Geerts, 2020). The technical principles of partial denture design must be observed as a whole – none of the biomechanical aspects in isolation render the RPD clinically safe and satisfactory.

- The importance of RPD design should continue to be emphasised in undergraduate training.
- Refresher courses on principles of partial denture designing and related topics should be held on a frequent basis for clinicians and technicians in both private and public sectors, especially when RPDs are the only economically viable option for tooth replacement.
- Technicians should be encouraged to provide more detailed laboratory slips that incorporate an area to draw RPD designs.
- Clinicians should take responsibility for the RPD design for each case so that provision of removable partial dentures is evidence-based, and not iatrogenic.
- An ethical and legal document guiding and emphasising the roles of clinicians in the prescription and design of RPDs in South Africa should be considered by the regulatory authority.

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APPENDIX A – Ethical clearance certificate

EKURHULENI HEALTH DISTRICT
PUBLIC HEALTH UNIT

Enquiries: Mpho Manamela
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E-mail: Mpho.Manamela@gauteng.gov.za

6 March 2019

TO: WITS ETHICS COMMITTEE

SUBJECT: PERMISSION TO CONDUCT RESEARCH BY Dr R DAYA IN EKURHULENI DISTRICT, GAUTENG

In principle permission is granted to Dr R Daya, to conduct research in Ekurhuleni district for the following research topic: **The design of removable partial dentures fabricated in dental laboratories serving the private sector and the public health dental clinics in the district of Ekurhuleni, Gauteng Province, South Africa.**

The aim of this study is to assess the technical quality of removable partial dentures in relation to bio-mechanically accepted principles, using dentures fabricated in dental laboratories contracted to the Ekurhuleni district which also provide a service to the private sector, so that comparisons between sectors could be made.

Objectives

1. To assess the frequency of denture prescriptions sent to the laboratories prior to RPD fabrication.
2. To determine the extent to which the RPDs meet minimal standards of design and fabrication in order to assess the technical quality of the dentures.
3. To compare the designs of RPDs made in the public, to the private sector.

Ekurhuleni District Research Committee will review the proposal and will only give permission once we have received the final ethical clearance.

Yours sincerely,

____

Dr Ronel Kellerman

EKURHULENI DISTRICT RESEARCH COMMITTEE CHAIRPERSON

Date: 6 March 2019

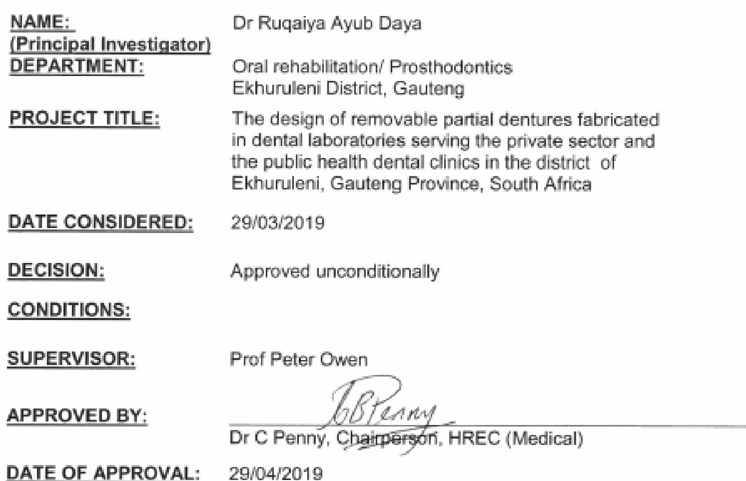
40 Catlin Street, Germiston, 1401 – Private Bag X 1005, Germiston, 1400

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R14/49 Dr Ruqaiya Ayub Daya

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190314



NAME: **(Principal Investigator)** Dr Ruqaiya Ayub Daya

DEPARTMENT: Oral rehabilitation/ Prosthodontics
Ekhuruleni District, Gauteng

PROJECT TITLE: The design of removable partial dentures fabricated in dental laboratories serving the private sector and the public health dental clinics in the district of Ekhuruleni, Gauteng Province, South Africa

DATE CONSIDERED: 29/03/2019

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Prof Peter Owen

APPROVED BY: Dr C Penny, Chairperson, HREC (Medical)

DATE OF APPROVAL: 29/04/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. 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 resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed March and will therefore be due in the month of March each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B – Data capture sheet

Data capture sheet 1

Clinical Procedures											Technical / Laboratory procedures						
					Articulation Y/N						Surveying		Design				
Case Number	Primary Imps: Material used	Special Tray? Y/N	Secondary Imps: Material used	Bite Blocks? Y/N	Hand	Hinge	Av. Value	Semi-adj	Try-In? Y/N	Recalls? No.	Dentist Y/N	Technician Y/N	Dentist verbal? Y/N	Dentist written? Y/N	Dentist drawing? Y/N	Technician Y/N	Technician Drawing? Y/N

	Technical / Laboratory procedures										Photographs						
	Design features										Whether available Y/N						
Case Number	Kennedy Class	Base: metal or acrylic	Number of rests	Number of rest seats prepared	Specify which teeth have rests	Number of clasps	Specify which teeth have clasps	Clasp material	Number of teeth with prepared guide planes	Specify which teeth have guide planes	Primary cast	Final cast	Close-up of rest seats	Close-up of guide planes	Design	Denture on cast	Denture off cast

APPENDIX C – laboratory script and laboratory script examples

BURG1459

TEL (011) 896 5376
P.O. BOX 8966

M.M. 059 EEA 19 FILE.

Description of Case:

1. Acrylic denture work:

F/F	F/- or -/F	P/- ✓	-/P ✓	Reline	Remodel	Repair

2. Orthodontics:

Bite Plate	Mouth Guard	Other	

Partial upper + partial lower

3. Chrome cobalt:

F/-	P/-	-/P	Repairs

Full description of work to be set out here:

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

Make and type of tooth

Shade No A2 Mould No Eray 45H

Special Trays Time 13/06/2019

Bite Time

Try-in ✓ Time 20/06/2019

First re-try ✓ Time 4/7/19

Second re-try Time

Third re-try Time

Finish Time

INSTRUCTIONS AND REMARKS

Figure 18. Operator’s instructions to laboratory for RPD

TRIPOLIS COU...

Description of case -

1. Acrylic denture work:

F/F	F-Upper	F-Lower	U-Partial	L-Partial	Reline	Repair

2. Crown and bridge work:

3/4 Crown	Bridge	Zirconia	VMK	Inlays	Implants	Other Specify

3. Other (To be described fully below):

Full description of work to be set out here:

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
							X	X	X						
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

Shade No.: A2.
Mould No.:
Special trays: Time:
Bite: Time:
Try in: ✓ 18/07/2019 Time: 10:00
First re-try: Time:
Second re-try: Time:
Third re-try: Time:
Finish: Time:

INSTRUCTIONS AND REMARKS

Please add 2 clasps

Dentist's Signature

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Figure 19. Operator's instructions to laboratory for RPD

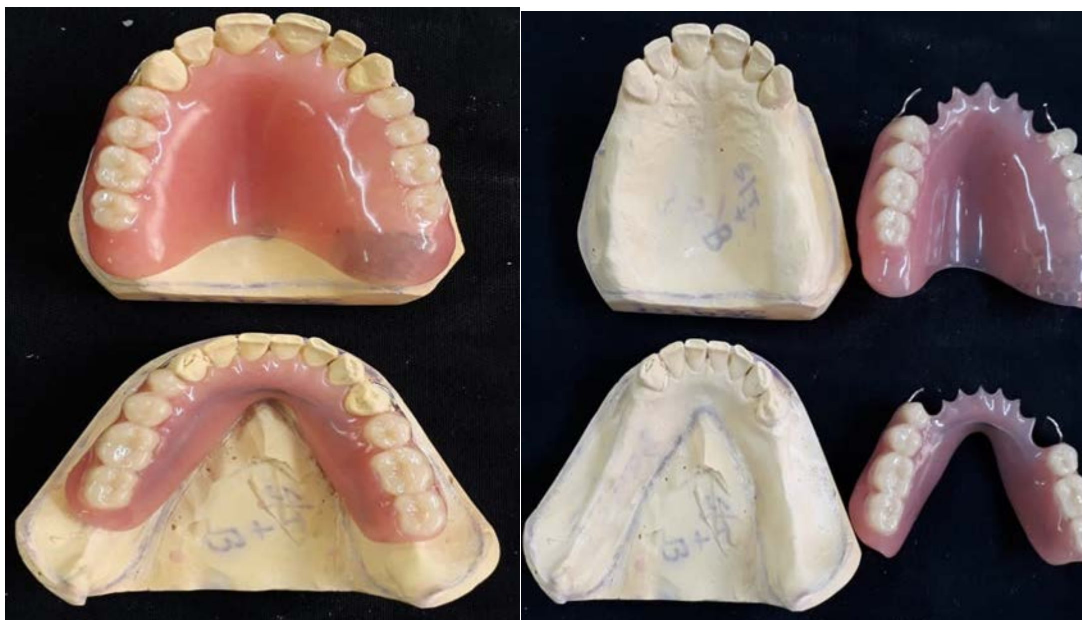

Figure 20. Examples of acrylic based partial dentures without rests, but including clasps

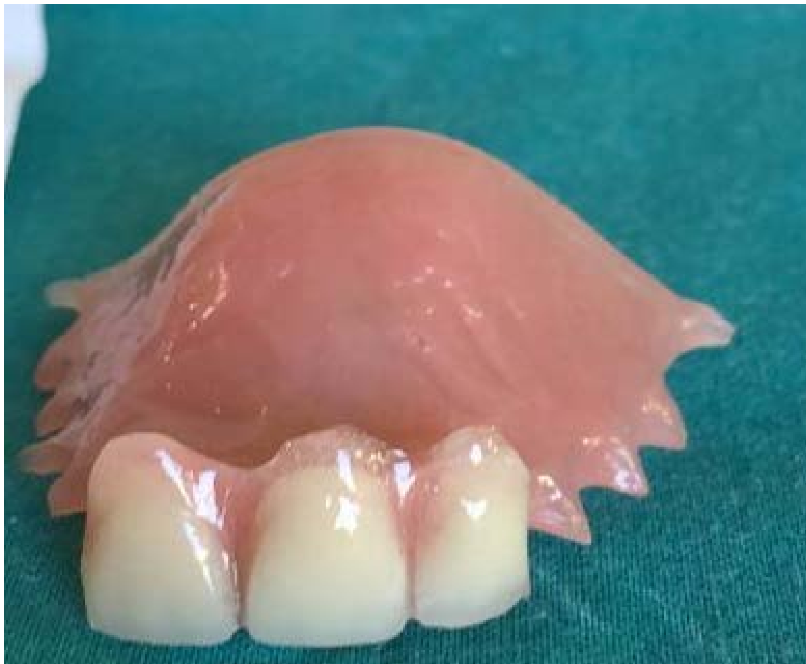

Figure 21. Example of acrylic-based partial denture without rests or clasps

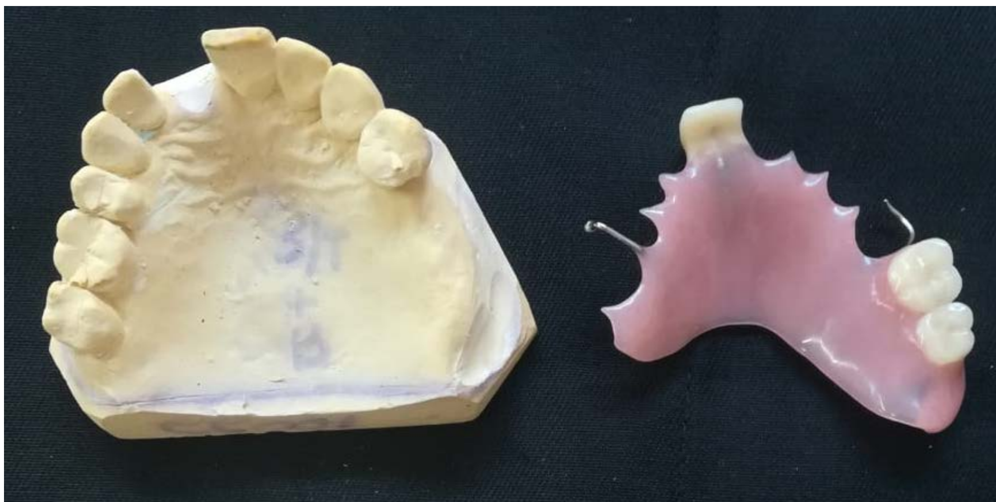

Figure 22. Example of an acrylic partial denture with a C-clasp and a ball clasp.

APPENDIX D – TURNITIN report

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