PREVALENCE OF IMPACTED TEETH AT A DENTAL SCHOOL ORTHODONTIC CLINIC, JOHANNESBURG, SOUTH AFRICA

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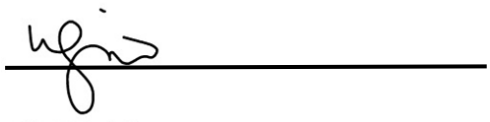
Declaration

I, Mollyn Chikanga, declare that this Research Report, **"Prevalence of impacted teeth at a dental school orthodontic clinic, Johannesburg, South Africa"**, is my own, unaided work. It is being submitted for the Degree of Master of Science in Dentistry at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

16th Day of September 2025 in Mbabane Eswatini

Dedication

This work is dedicated to my son, Ayden.

Acknowledgements

First and foremost, praise and thanks to God, the Almighty, for the blessings and strength throughout my research work.

I want to express my deepest and sincere gratitude to Professor Phumzile Hlongwa (PhD), my supervisor, for allowing me to do this research and providing invaluable guidance. I heartily appreciate her for the discipline and resilience that she instilled in me, and regardless of the challenges, I owe it to myself to get to the finish line. Thank you, Prof!

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Abstract

Objective

Tooth impaction is commonly seen in dental practice. Early diagnosis of tooth impaction could reduce treatment time, complexity, complications and costs. The study aimed to determine the prevalence of impacted teeth in orthodontic patients treated at a dental school in Johannesburg.

Materials and methods

A retrospective, record review, cross-sectional study from 1 January 2015 to 31 December 2019 was conducted. Pre-treatment orthodontic panoramic radiographs were reviewed for impacted teeth. The type and level of impaction of all the teeth were classified using various classification systems for incisors, canines, premolars and molars. The distribution of impactions according to the affected jaw (mandible or maxilla) and affected side (left/right) was determined.

All statistical tests were conducted at 5% significance level.

Results

We evaluated 323 panoramic radiographs, of which 113 (35%) had at least one impacted tooth. The median age of the sample was 12 years (IQR 9; 18) years, and a female-to-male ratio of 1:1.31. The total number of impacted teeth was 251, and 155 (61.8%) were in the maxillary arch, while 96(38.2%) were in the mandibular arch. The most impacted teeth were the maxillary canines (n=70; 27.9%), followed by mandibular third molars (n=49; 19.5%) and then maxillary third molars (n=41; 16.3%). Males accounted for 55.7% of mandibular impaction and 58.4% of maxillary impactions. Statistical analysis revealed a significant association between the side and maxillary impactions (P=0.002). Furthermore, age was significantly associated with mandibular impaction (P<0.001).

Conclusions

The prevalence of tooth impaction was 35.0%. The maxillary canines were the most impacted teeth, followed by the mandibular third molars. Early detection of impacted teeth can help with early intervention to prevent the severity of malocclusion.

Keywords: Tooth impaction, panoramic radiograph, prevalence, orthodontic patients, South Africa.

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Abbreviations/Acronyms

2D	Two- Dimensional
3D	Three-Dimensional
AAOMS	American Association for Oral and Maxillofacial Surgeons
ADS	American Dental Association
CBCT	Cone beam computed tomography
CT	Computed tomography
DL	Deep learning
Dr	Doctor
IQR	Interquartile range
KPG Index	Kau, Pan and Gallerino Index
MC	Mollyn Chikanga
MRI	Magnetic Resonance Imaging
PhD	Doctor of Philosophy
PI	Principal investigator
SA	South Africa
VB	Vuyo Bomvana
WHO	World Health Organisation
WOHC	Wits Oral Health Centre

Chapter 1:Introduction

1.1 Background

Tooth impaction is frequently seen in dental practice, including in orthodontic clinics.[1-7] Tooth impaction may be as a result of local factors, which include physical obstruction, insufficient space in the dental arch due to skeletal discrepancies, prolonged retention or premature loss of primary teeth and a tooth-arch size discrepancy.[8, 9] Systemic causal factors include genetic disorders, endocrine deficiencies and previous irradiation to the jaws.[6, 10] Tooth impaction may occur in any position of either or both jaws, with different inclinations and angulations, presenting as a single tooth or multiple teeth impactions.[11]

Early detection and prevention of tooth impaction could reduce treatment time, complexity, complications and costs. A comprehensive clinical examination to detect tooth impaction should incorporate a thorough family history, visual inspection, and tactile evaluation. Detailed assessment of impacted teeth for their location, angulation, and orientation is essential for clinical management and treatment planning. The position of impacted teeth is accurately determined using a combination of occlusal, periapical and panoramic radiographs.[11] Alternatively, pairs of images taken with known different perspectives can be used for localisation using the parallax technique.[12] Advanced three-dimensional (3D) techniques, such as cone-beam computed tomography (CBCT), computed tomography (CT) and magnetic resonance imaging (MRI), overcome the limitations of traditional two-dimensional (2D) imaging.[13] The use of CT has a significant disadvantage due to high radiation doses.[14] However, the CBCT scans have reduced radiation exposure, and they can produce 3D imaging of the dental structures.[15]

There is extensive literature on the prevalence of tooth impaction from studies in different regions of the world.[5, 11, 16-22] Some studies focused on specific teeth or tooth groups.[11, 16-20] A few studies have analysed the prevalence of tooth impaction for all tooth groups.[5, 21, 22]

Literature suggests that most tooth impactions are due to local and systemic factors, with a few being due to unknown causes.[23] Previous authors have classified impacted teeth due to their inclination, angulation or position in the tooth-bearing tissues of the jaws.[24-27] Classifications are necessary to aid clinicians in defining the type and depth of the tooth as they make proper diagnoses and devise appropriate treatment plans. The most common classifications include Winter's[24], Pell and Gregory's classifications[25] for third molar

impaction, and the Yamamoto and co-workers' classification[26] for canines and second premolars. Other authors have also described practical classifications for other teeth.[28, 29]

Tooth impaction can be detected clinically by visual inspection and tactile examination, and diagnosis can be confirmed radiographically. The radiographic examination includes 2D occlusal, periapical, panoramic views and 3D imaging such as CBCT, CT and MRI. Despite their shortcomings, panoramic radiographs are commonly used for tooth impaction detection and diagnosis. Panoramic radiographs are relatively cheaper and provide invaluable information about both jaws.[30]

1.2 Definition of an impacted tooth

An impacted tooth is a tooth that is unlikely to erupt into its normal position in a reasonable time, even though its root has developed more than three-quarters of its final length.[9] It has also been defined as a tooth that has been prevented from completely erupting into its normal functional position due to lack of space, obstruction by another tooth or inadequate alveolar bone length.[13] Furthermore, tooth impaction may be partial where the tooth is not entirely encased in bone and thus communicates with the oral cavity. On the contrary, a wholly impacted tooth is encased in bone without communication with the oral cavity.[31] In the exception of third molars, the maxillary canines are most likely to be affected, followed by mandibular second premolars, mandibular first and maxillary second premolars and then maxillary central incisors.[3, 21]

Primary tooth impactions are extremely rare, but second primary molar impactions have been reported, with ankylosis playing a significant role in the aetiology.[32]

1.3 Prevalence of tooth impaction

Impacted teeth can occur in both jaws.[5, 21] Impacted teeth prevalence differs substantially among distinct populations and ethnicities.[33] The prevalence of tooth impaction is between 8-29% [4-6, 21, 34-36], and of these third molar impactions represented up to 98.1% of all impactions.[4, 6, 21, 35] Kramer and Williams in their study on a predominantly Afro-American population reported an 18.3% tooth impaction prevalence, 94.1% being third molars.[21] Studies on a Swedish population by Ahlqwist and Grondahl revealed an 8.3% prevalence rate of tooth impaction, 84.9% of which were third molars.[4] In China, Chu and co-workers discovered a higher prevalence of tooth impaction of 28.3%, and 98.1% of these impactions were third molars.[6] Similar findings were observed in Saudi Arabia, Al-Ramil and co-workers reported a tooth impaction prevalence of 27.1% and a similarly high proportion being third molars (93.5%) in their study on 1985 Al Ahsa Saudi patients.[13] Zraiki and

Kaseeh reported a 21.6% tooth impaction prevalence in a Syrian population, 92.7% were third molar impactions.[5]

In a study on a South African population in 1982, Brown and co-workers found that maxillary third molar impactions represented 38.0% of third molar impactions.[37] Another study by Ishwarkumar and co-workers on a South African population also revealed a significantly higher mandibular third molar impaction (56.4%).[19] Brown and co-workers' observation was contrary to Kramer and Williams, who reported that the maxillary third molar impactions represented 62.6% of all third molar impactions in a predominantly black American population. Kramer and Williams' unique finding was attributed to the fact that their study was done on patients who had been referred to oral surgeons. Maxillary third molar impactions are more challenging to treat and, therefore, are most likely to be referred to oral surgeons.[21]

Maxillary canine impaction prevalence varies from 1.73% to 9.8%, depending on ethnicity of the population [8, 21, 22, 38] The majority of impacted canines occurred in the maxilla (83.5%) and 16.5% in the mandible.[38] Maxillary canine impaction is more common on the palatal side and is more common in females.[35] Premolar impactions occur infrequently, with an overall prevalence of 1.03% reported.[39] The mandibular second premolar had a prevalence of 0.64%, followed by the maxillary second premolar at 0.22% and then the mandibular and maxillary first premolars at 0.11% and 0.05%, respectively.[39] A higher prevalence of 2.1% mandibular premolar impaction has also been reported.[38] The maxillary incisor impaction is not uncommon,[20, 34, 40], with a reported prevalence of between 0.1% and 0.65%.[40] According to Topkara and Sari, the prevalence of incisor impaction was 0.65%, comprising 0.59% (n=9) of maxillary incisor impactions.[41] The prevalence of maxillary incisor impaction has been reported to be as prevalent as that of canine impaction.[41, 42]

Supernumerary tooth impactions are also encountered in dental practice, occurring in 0.5 to 2.7% of the population.[13, 34, 41, 43-45] Most impacted supernumerary teeth were found in the premaxilla, with a male predilection and more frequent in the permanent dentition.[34] Supernumerary teeth are often abnormal in form and are usually conical-shaped, tuberculate, and may appear as odontomes or supplemental teeth.[3, 46]Impacted first and second molars are rare and challenging for orthodontists and oral surgeons to manage.[8] In a multi-centre study, the prevalence of permanent second and first molar impaction was reported to be 0.15% and 0.03%, respectively.[47] Studies have reported that the mandibular second molar impaction occurred more frequently, with prevalence ranging from 0.03% to 0.3%.[8, 48-50] Unilateral impaction represents the predominant pattern in mandibular second molar impaction cases.[8]

1.4 Aetiology of tooth impaction

Tooth impaction can indeed result from various local factors that include mechanical obstruction, limited jaw space due to insufficient maxillofacial skeletal development, premature loss of primary teeth, or a tooth-arch length discrepancy[9], ankylosis of deciduous teeth, supernumerary teeth, tumours, and trauma.[23] Generalised factors that can cause tooth impaction are often associated with systemic disorders and syndromes.[9] Genetic disorders, endocrine dysfunctions, and prior jaw irradiation are systemic causal factors for tooth impaction.[6, 10]

Mandibular third molar impaction is attributed to insufficient space in the retromolar area, specifically between the distal surface of the second molar and the mandibular ramus.[51] The reduced space is attributed to reduced jaw size due to evolution.[52, 53] Observations indicate that third molar impaction is significantly less likely to occur following the extraction of the second molar, implying enhanced eruption space.[54] Orthodontic treatment involving premolar extraction demonstrates a decreased likelihood of third molar impaction, highlighting space deficiency as a major contributing factor.[55]

There are two contemporary theoretical causes for maxillary canine impaction: guidance and genetic theories.[3, 56] The aetiology of maxillary canine impaction is categorised into four primary categories: local hard tissue obstruction, local pathological conditions, aberrant lateral incisor development, and hereditary or genetic influences.[57-59] Buccal canine impactions are mainly associated with inadequate arch length space, as reported by Jacoby and co-workers.[60] Canine impaction results from prolonged deciduous canine retention, permanent tooth bud malposition, alveolar clefts, ankylosis, cystic/neoplastic formations and radicular dilacerations.[61] The exact aetiology of palatally impacted canines remains unclear, but two primary theories have emerged: guidance and genetic theories.[59, 60] The guidance theory proposes that palatal canine impaction results from local predisposing factors that interfere with the expected eruption path and may include congenitally missing lateral incisors, supernumerary teeth, odontomas, or transposition of teeth.[60, 62] From a genetic perspective, palatally impacted canines are frequently accompanied by other dental anomalies, such as tooth size, shape, number and morphology variations. Research suggests that these anomalies may be genetically linked.[56, 57, 59]

Premolar impaction is commonly associated with crowding or as a result of an early loss or prolonged retention of the primary molar.[46] The aetiology of supernumerary teeth has not been definitively determined, and various theories have been proposed to explain their occurrence. The most common view is that supernumerary teeth result from horizontal proliferation or hyperactivity of the dental lamina.[63-65] Genetic syndromes such as Gardner syndrome, Down

syndrome, cleidocranial dysplasia, and familial influences have also been associated with impacted supernumerary teeth.[3, 34]

Incisor impaction is rare, but when it occurs, maxillary incisors are often the affected teeth.[5] Maxillary incisor impaction may be due to obstruction or trauma.[9] The obstructive causes include the presence of supernumerary teeth, odontomes and cysts. Other causes include dilaceration of the root, mal-positioning of the unerupted tooth germ, lack of space and previous trauma to the primary incisor.[66, 67]

Molar impaction, except for the third molar, is rare. First permanent molar impaction usually occurs due to systemic causes and rarely involves local factors such as pathological obstructions.[68] Second mandibular molar impaction has been chiefly attributed to anterior and posterior crowding. However, it has been suggested that differential mesial and distal root development and mesial angulation are the significant causes of second molar impaction. Shapira and co-workers concluded that crowding could be a secondary factor in second mandibular molar impaction.[69]

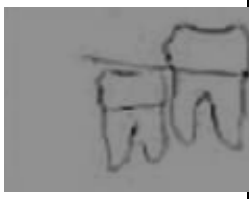
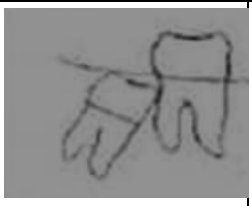
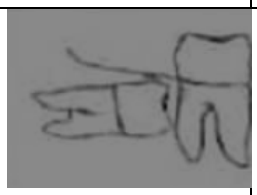
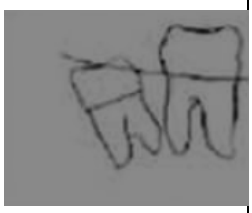
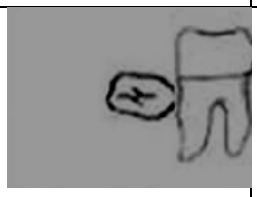
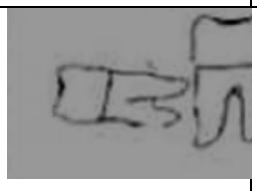
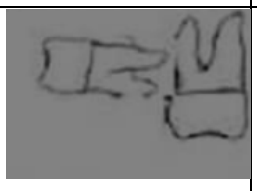
1.5 Classification of tooth impaction

Tooth impaction classifications are necessary to allow the clinician to define the type and depth of the impacted tooth in the alveolar bone. The definition will aid in assessing the degree of difficulty of clinical management.[24, 26-29, 70-72]

1.5.1 Third molar impaction classification

The degree of third molar impaction is determined by the impacted tooth's angulation and is classified using Winter's classification.[24] The classification makes reference to the angle formed between the long axes of the second and third molars.[24] The descriptions are shown in Table 1.1. Other angulations, such as *bucco*-lingual, *mesio*-inverted, *disto*-inverted and *disto*-horizontal, also exist; however, they are uncommon.

Table 1.1Third molar impaction classification

Classification	Jaw		Description
	Mandibular	Maxillary	
Vertical			The third molar's long axis aligns parallel to the second molar's long axis, with its crown positioned apically relative to the second molar's cervical line.
Mesio-angular			The third molar's long axis bisects the long axis of the second molar at or above the occlusal plane.
Horizontal			The third molar's long axis bisects the second molar's long axis at a right angle.
Disto-angular			The long axes of the third molar and second molar are divergent, with the crown of the third molar inclined distally.
Bucco-lingual			The third molar is buccally or lingually tilted.
Others			The third molar is facing away from the second molar.
			Inverse - the third molar is inverted as related to the second molar.

Source: [24]

The level of impaction is determined using Pell and Gregory classification.[25] The classification describes the impacted tooth relative to the ramus of the mandible (Class 1, 2, 3) and its relative depth in bone (Position A, B, C), as shown in Figure 1.1.

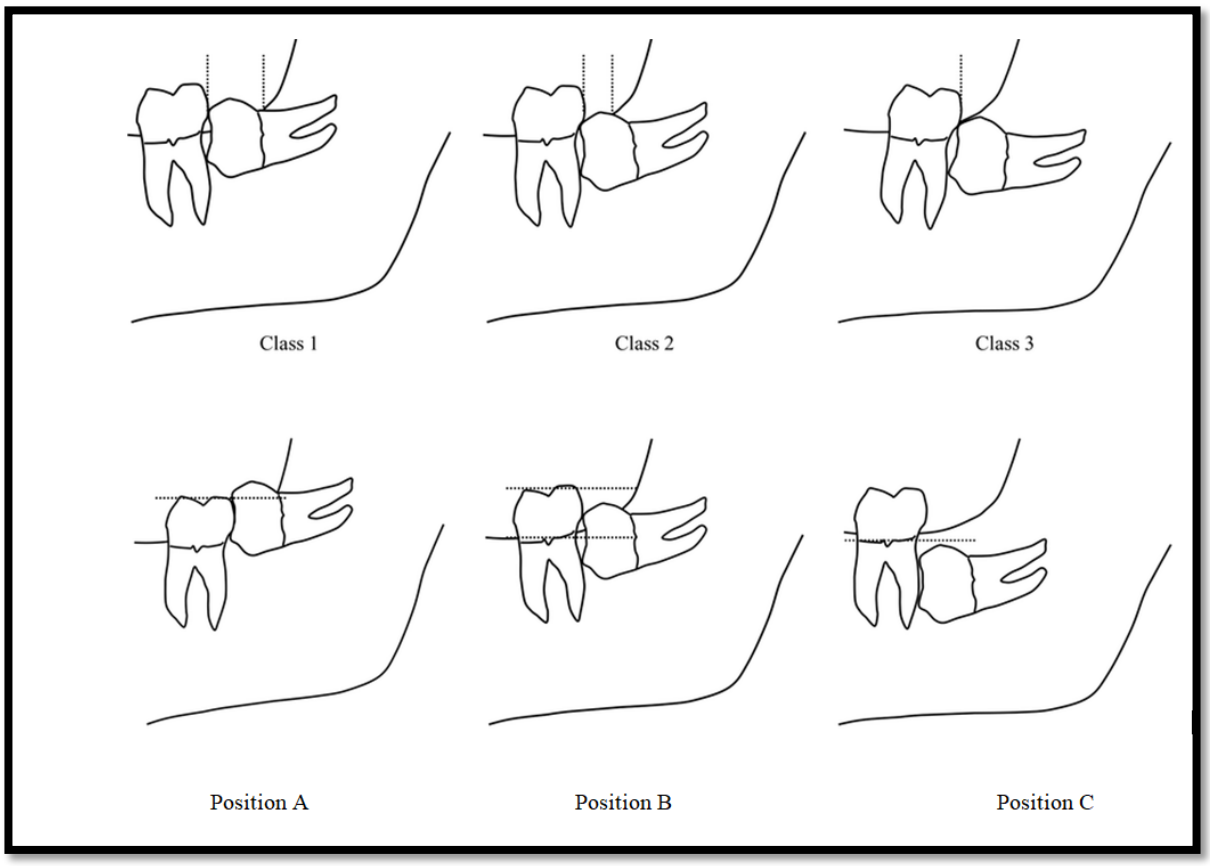


Figure 1.1 Third mandibular molar impaction classification

Source:[73]

- Class 1: The available space between the anterior border of ascending ramus and distal aspect of second mandibular molar is sufficient for the crown of the third molar.
- Class 2: Insufficient space exists between the ramus and the second molar for the third molar crown. It indicates partial bone coverage of third molar crown.
- Class 3: The third molar is fully encased in the ascending ramus bone due to insufficient space.
- Position A: A partially erupted third molar whose highest point is at or above the occlusal plane.

- Position B: The highest point of impacted third molar is below the occlusal plane but above the cervical line of second molar.
- Position C: A completely impacted third molar, and its highest point is below the cervical line of second molar.[25]

Maxillary third molars are classified as impacted when the lowest portion of the crown of the impacted third molar is above the occlusal plane of the second molar.[74] Joudzbalys and Daugela developed a classification system for third mandibular impactions and extraction difficulty, which assesses the impacted tooth's spatial relationship to the surrounding anatomical structures, including the mandibular ramus, second molar, alveolar crest, and mandibular canal, based on anatomical and radiological factors.[53] The spatial positioning may be done clinically and by using CBCT and panoramic radiographic images.[53]

The American Dental Association's (ADA) American Association of Oral and Maxillofacial Surgeons (AAOMS) classifies mandibular third molar impaction in consideration of the overlying tissue.[75] Surgical steps are prescribed for each type. It is mainly used by health insurance and surgeons in the United States of America to institute charges for their services.[75] In this system, third molar impaction is classified as follows;

1. Soft tissue impaction - requires surgical incision of overlying soft tissue for tooth extraction.
2. Partial bony impaction - requires soft tissue incision, flap elevation, bone removal and tooth removal (with or without sectioning).
3. Full bony impaction - requires soft tissue incision, flap elevation, osteotomy and sectioning of the fully encased tooth for removal in fragments.[75]

1.5.2 Canine impaction classification

Many canine impaction classification variations have been proposed.[26, 28, 71] Chapokas and co-workers introduced a maxillary canine impaction classification system, categorising them into three distinct classes based on their spatial relationship to the alveolar ridge and adjacent dental structures as *Class I* - palatal impactions, *Class II* - at the centre of the alveolar ridge or labial to the alveolar crest, without overlapping the root of the adjacent lateral incisor and *Class III* - labial to the long axis of the adjacent lateral incisor root.[28] The proposed classification system serves as a clinical decision-making tool, providing guidance on the most appropriate surgical intervention strategy for promoting eruption of impacted maxillary canines.[76] Yamamoto and co-workers classified canine and second premolar impactions according to impacted tooth's long-axis angle relationship to the

occlusal plane. This classification uses panoramic radiographs to estimate the angle between tooth and occlusal plane. Seven types of impaction are identified for canines[26] as shown in Figure 1.2.

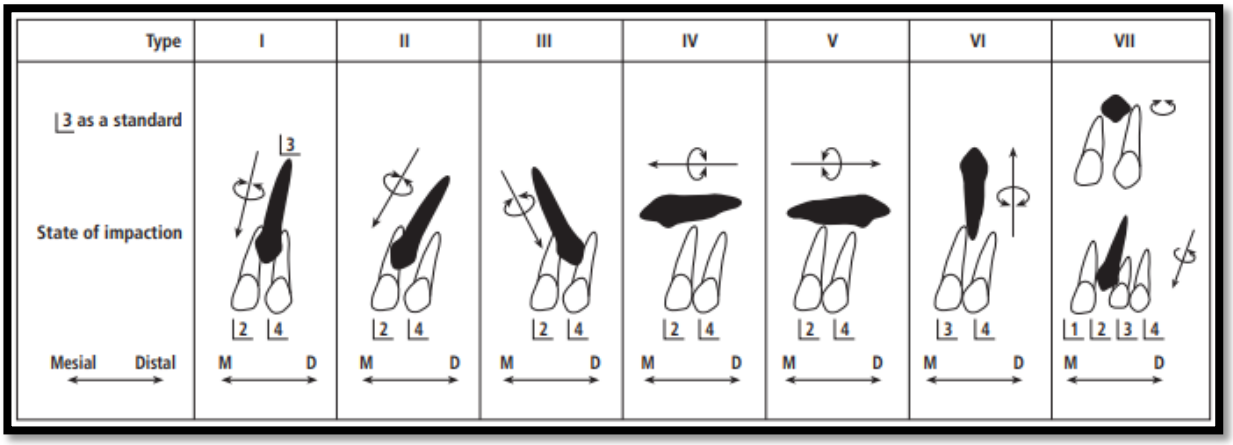


Figure 1.2 Canine impaction classification

Source: [26]

- Type I — vertical impaction, canine interposed between the lateral incisor and first premolar. There is a risk of lateral incisor root resorption.
- Type II — mesial inclination: the canine overlaps the lateral incisor, providing a distal tipping of the lateral incisor.
- Type III — distal inclination, overlapping first premolar.
- Type IV — horizontal impaction with crown mesially positioned.
- Type V — distal horizontal impaction.
- Type VI — inverse impaction, the canine is directed toward orbital fossae.
- Type VII — labial/palatal impaction where the canine long axis is in the horizontal direction, and the crown is placed buccally or canine transposition [26]

Yavuz and co-workers investigated the incidence of impacted mandibular canines and associated pathologies of impacted mandibular canines, introducing a novel classification system.[71] The classification framework categorises impacted mandibular canines based on two primary parameters: angulation (vertical, horizontal, distoangular and mesioangular) and depth (Levels A-C).

- Level A- the impacted canine's crown is aligned with cervical line of the adjacent teeth.

- Level B- the impacted canine's crown is positioned between cervical line and root apices of adjacent teeth.
- Level C- the crown of the impacted canine tooth is located beneath the apices of adjacent teeth.[71]

In 2009, Kau, Pan and Gallerano suggested a Three-Dimensional (3D) classification system for canine impactions - the KPG Index. The 3D CBCT images were used to measure, classify and assess the degree of difficulty in treating impacted canines. A measuring scale with three key perspectives was created. The cusp and root tips were given a number from zero to five (in order of divergence from the normal) in the three dimensions from the pre-treatment CBCT images. The cumulative score of cusp tips and root tips in three radiographic views predicts the anticipated treatment complexity, facilitating a standardised canine impaction classification.[77]

Aljabri and co-workers developed deep learning (DL) models that classify the type of canine impaction based on the classification of Yamamoto and co-workers.[78] The proposed model may assist dentists by automating the canine impaction prediction process for faster and more accurate diagnosis.[78]

1.5.3 Second premolar impaction classification

Impaction of the second premolar was classified into seven types[26] based on the position of the second primary molar, as shown in Figure 1.3.

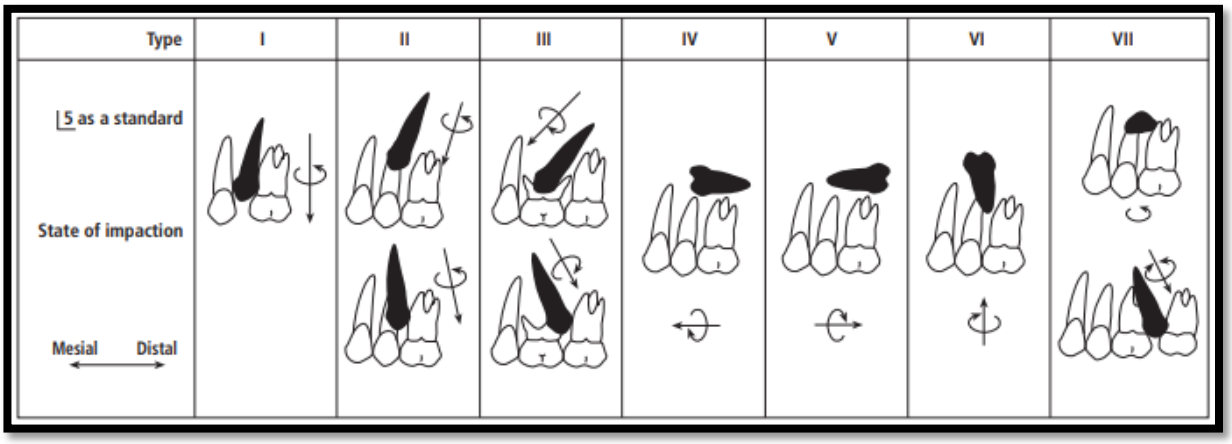


Figure 1.3 Second premolar impaction classification

Source: [26]

- Type I — vertical impaction, impacted second premolars located between the first premolar and first molar, with the canine inclined distally or first molar inclined mesially. This is often due to early loss or incomplete eruption of the deciduous second molar. It is more common in the mandible because of the hard cortical bone, and second premolar eruption is often incomplete, with curved roots.
- Type II — the impacted second premolar is near the apex of first premolar, with limited eruption space.
- Type III — retained second deciduous molar causes impaction despite adequate eruption space. The impacted second premolar may be inclined mesially or distally.
- Type IV — mesial horizontal orientation, parallel to occlusal plane.
- Type V — distal horizontal orientation, parallel to the occlusal plane.
- Type VI — inversely impacted second premolars.
- Type VII — second premolars with axis inclined in the *bucco*-lingual/palatal direction or abnormally located.[26]

Mehta and co-workers (2017) suggested a mandibular second premolar impaction classification, including ideal treatment for each class.[29] Seven types of second mandibular premolar impaction were described as shown in Figure 1.4.

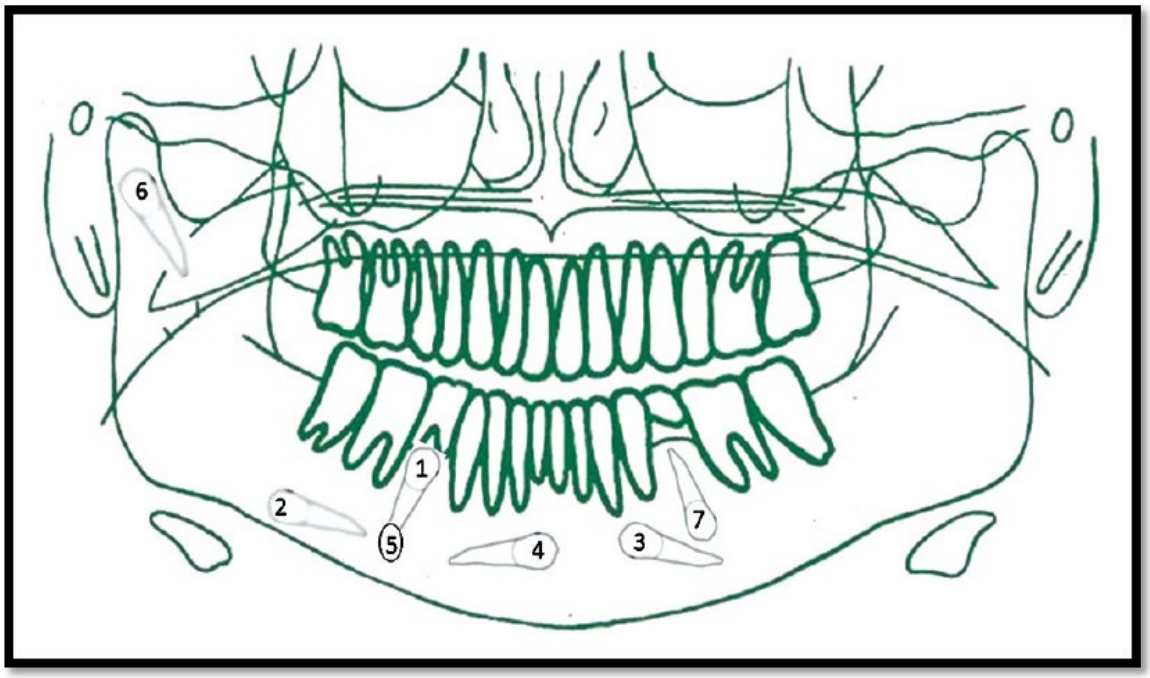


Figure 1.4 Second mandibular premolar impaction classification

Source:[29]

- Type 1 - 0° inclination
- Type 2 - distal inclination, in the body of the mandible below the apices of the molars.
- Type 3 - mesial inclination, positioned below the same side apices of canines/ incisors and not crossing the midline.
- Type 4 - mesial inclination, transmigrated below the apices of the incisors crossing the midline.
- Type 5 - 90° inclination, positioned horizontally.
- Type 6 - positioned in the ascending ramus, coronoid process or condyle.
- Type 7 - 180° inclination, inverted.

1.5.4 Incisor impaction classification

Maxillary incisor impaction is infrequently seen in general dental practice, and its treatment is challenging because of the aesthetic position of the tooth.[27] Mitchell and Bennett classified the distance of the unerupted tooth from the occlusal plane into three groups: near, mid and far.[72] Smailene and co-workers' study analysed the impacted tooth's vertical position in relation to the contralateral erupted incisor.[27] The thirds of the erupted contralateral tooth were used, and three possible vertical positions were defined as shown in Figure 1.5.

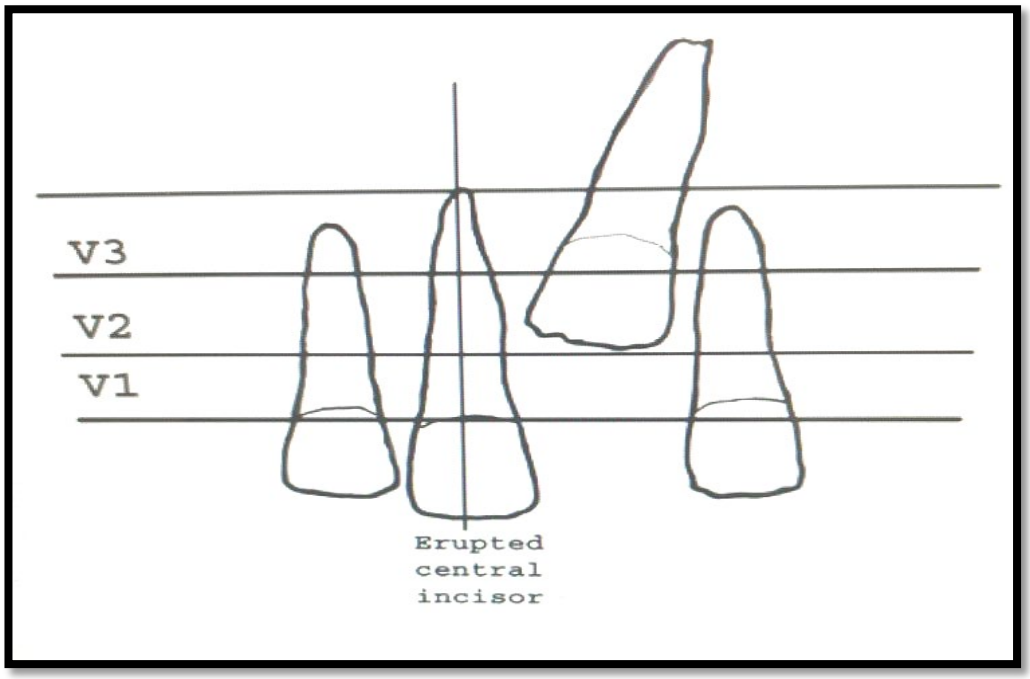


Figure 1.5 Incisor impaction

Source: [27]

For classification, the root of the erupted contralateral incisor was divided into three distinct sectors:

- V1 – the coronal sector- encompassing the gingival third.
- V2 – the middle sector, corresponding to the middle third.
- V3 – the apical sector, comprising the apical third.[27]

The purpose of these classifications was for diagnosis and treatment planning. With the advent and widespread use of lower X-ray dose 3D imaging, better and more accurate spatial localisation of impacted teeth is becoming possible, leading to better classification systems.

1.6 Orthodontic implications and management of impacted teeth

Impacted mandibular third molars interfere with uprighting of mandibular first and second molars during anchorage preparation and molar distalisation. Impacted third molars are also prone to caries, pericoronitis and odontogenic cyst formation.[9] As a result, they need to be electively extracted preceding treatment with either fixed or removable appliances.[53]

Canines are the cornerstones of an ideal and mutually protected occlusal scheme. They play a key role in aesthetics and dental arch harmony.[79] The most common complications from canine impaction include root resorption of an adjacent permanent tooth, cyst formation, swelling and pain.[80]

Spontaneous eruption of the canine may result if the primary canine is extracted, and the permanent ectopic canine crown is positioned favourably. Three surgical techniques proposed for canine surgical eruption are gingivectomy, the apically positioned flap and closed eruption. In cases of unfavourable impaction or transmigration, orthodontic eruption becomes very challenging, and it becomes prudent to extract the tooth, thus preserving the alveolar bone and avoiding damage to the adjacent teeth.[81]

Supernumerary teeth may impede the eruption of normal teeth.[9] Supernumerary tooth impaction may be associated with pathological changes such as cystic formation and impede orthodontic tooth movement.[9] When there is no specific indication for their removal, no treatment is necessary, but constant monitoring is required to identify any pathology that may develop.[3] Literature specific to the treatment and management of impacted premolars is sparse.[82] The appropriate treatment selection involves considering underlying aetiological factors, space requirements, need to extract the primary molars, degree of impaction, and the impacted premolar's root formation.[83, 84] Mehta and co-workers, in addition to classifying mandibular second premolars, suggested treatment protocols for each scenario, as shown in Table 1.2.[29]

Table 1.2 Second premolar classification and treatment

Type	Position	Description	Treatment
1	0° inclination.	In the line of the arch, removing the primary molar and adequate space can allow eruption.	It's the easiest to treat. Extract the primary molar if there is enough space or create space for the premolar if space is inadequate.
2	Distal inclination	Positioned in the body of the mandible below the apices of the molar	Wait and watch, and surgical removal is recommended if associated with cystic change
3	Mesial inclination	Positioned below the apices of the same side, canine/incisors, but not crossing the midline.	Surgical repositioning can be attempted depending on inclination and position; otherwise, surgical removal is recommended.
4	Mesial inclination	Transmigrated and positioned below the apices of incisors crossing the midline.	Surgical removal recommended
5	90° inclination (horizontal position)	Rare and cannot erupt.	Surgical removal is recommended.
6	Positioned in the ascending ramus, or coronoid process or condyle	Rare and removal only is associated with symptoms or cystic change.	Wait and watch. However, surgical removal is recommended.
7	180° inclination; inverted position	Rare and cannot erupt into the oral cavity.	Surgical removal is recommended.

Source:[29]

1.7 Justification of the study/ Rationale

There is sparse information regarding the prevalence of tooth impaction in Africa, specifically South Africa (SA). The orthodontic clinic at Wits Oral Health Centre (WOHC) functions as a tertiary referral centre, thereby encountering a broad spectrum of cases, encompassing both routine and highly complex orthodontic presentations. Managing impacted teeth requires a multi-disciplinary approach involving maxillofacial surgeons, periodontists, prosthodontists, orthodontists and restorative dentists. A study on the prevalence of tooth impactions in orthodontic patients is crucial. It will help plan and manage the resources required to treat affected patients.

The orthodontic clinic at the WOHC is part of the training and academic platform. It is a referral centre for Gauteng Primary Health Clinics and the surrounding provinces of North West, Mpumalanga, Limpopo and the Free State. Due to its central location, the clinic serves a community that spans all social demographics. The orthodontic clinic offers specialised services designed to optimise patients' oral function, dental occlusion and d*ento*-facial aesthetics, ultimately enhancing their quality of life. These include preventive, interceptive and comprehensive orthodontics. During a routine orthodontic examination, one of the pathologies that may be seen is tooth impaction.

1.8 Aim of study

The study aims to determine the prevalence of impacted teeth in patients seen at a Johannesburg orthodontic dental school clinic.

1.9 Objectives of the study

1. To determine the prevalence of impacted teeth from pre-treatment panoramic radiographs of orthodontic patients presenting at the Orthodontic Clinic of the WOHC.
2. To classify the type and distribution of impacted teeth from the pre-treatment panoramic radiographs
3. To assess the distribution of impacted teeth between the two jaws.
4. To explore the association between the type of impaction and the affected jaw.
5. To analyse the association between ages, gender, affected jaw and side.

Chapter 2: Methodology

2.1 Study design

This retrospective, record review, cross-sectional spanned five years from January 1, 2015 to December 31, 2019. The study duration was selected to ensure a sufficient sample size, thereby enhancing the reliability and generalisability of the findings.

2.2 Study population

Pre-treatment orthodontic records in the postgraduate and undergraduate clinics during the five years of the study period in the Department of Orthodontics at the WOHC.

2.3 Sample size

A minimum sample size of 260 was calculated using StatCalc 32-bit for Windows, a sample size calculator with an expected frequency of 32%, a design effect of 1.0, and a 95% confidence level. From the possible estimated 1160 records, a randomised sampling method was used with a random start. The records were assigned a unique number following the order of presentation from 01 January 2015 to 31 December 2019. For the random start, numbers one to five representing the first five records were put in a hat, and a single number was picked. The number two was picked, making record number two the random start. To determine the systemic sampling factor, numbers three to five were again put in a hat and a single number was randomly picked. This time, the number three was picked; therefore, every third file was chosen until we reached our sample size of 260. Numbers three to five were used for the systematic random sampling to ensure a wider spread of the study sample across the population. If a record was picked but did not meet the inclusion criteria, the next record was selected, and the systematic random sampling was continued thereafter.

2.4 Inclusion criteria

- All orthodontic patient records, including children and adults without previous orthodontic treatment. Both primary and secondary dentitions were considered.
- Patients who had ideal panoramic radiographs taken before orthodontic treatment was commenced. An ideal panoramic radiograph provides great diagnostic information. The ideal panoramic image of diagnostic quality is characterised by accurate representation, sharp borders and optimal density.[12, 85] The Sirona Sidex XG- the Sirona Dental X-ray and Imaging

system software allows for image magnification. Image magnification was utilised to examine impactions in greater detail.

2.5 Exclusion criteria

- Records of patients who had previously undergone orthodontic treatment.
- Radiographs with suboptimal density and or poor contrast were excluded from the study to ensure high-quality results and accuracy.

2.6 Calibration, intra- and inter-observer variability

To ensure consistency in radiographic evaluation, the Principal Investigator (PI) underwent calibration by experienced examiner, VB. They both independently evaluated 33(10%) randomly selected panoramic radiographs. The examiners demonstrated a high level of agreement, with concordance on 30 records(91% correlation). A combined review of the three discrepant cases was done, and a consensus was reached. On a second date, 33 panoramic radiographs were randomly selected fourteen days later, and both of them independently examined them. The two examiners agreed on 32 of the 33 radiographs (97%), thereby confirming an acceptable inter-examiner reliability.

To account for intra-examiner reliability, 10% of the records were randomly selected, and the radiographic records were re-examined using the same criteria. The results were compared with those obtained in the initial examination. Of the 33 randomly selected records, the results agreed in all 33 assessments (100%).

2.7 Data collection

Pre-orthodontic treatment panoramic radiographs and clinical records were reviewed. The panoramic radiographs were acquired utilising the Orthophos XG 3D/Ceph (Sirona Dental Systems, Germany) with standardised exposure parameters: 60-90 kV, 3-16mA and an exposure time of 9.4-14.1 seconds.

The panoramic radiographs were viewed using Sirona Sidex XG, a Sirona Dental X-ray and Imaging system software. This system was installed in a computer (Intel (R) Core™5.7500 CPU@3.40GHz) with a display measuring 17.32inches wide and 9.84inches high, and a resolution of 1600x900 pixels. The PI analysed the panoramic radiographs using uniform lighting and environmental conditions with no interruptions per session of two hours each to avoid visual fatigue.

The designed data collection form, Appendix A, was used to record the age at diagnosis, gender, tooth impaction, type of impaction and affected jaw.

The type and level of impaction for the third molars were classified using Winter's and Pell and Gregory classifications.[24]

Yamamoto and co-workers' [26] classifications were used to review the type of canine and second premolar impactions. The vertical position of impacted maxillary incisors was assessed using Smailiene and co-workers' incisor vertical position criteria.[27]

The first and second molar impaction was classified according to Winter's classification system.[24] The occlusal plane was used as a reference to determine the depth of the first and second permanent molar impaction.[86] Considering the accepted eruption time, teeth were defined as impacted when they remained in the jaw two years after their respective mean eruption age as shown in Table 2.1 below.[87]

Table 2.1 Mean chronological age for the emergence of permanent teeth

Tooth	Females (years)	Males (years)
Maxillary central	6.7	6.8
Maxillary lateral	7.7	8
Maxillary canine	11.2	11.6
Maxillary first premolar	10.3	10.6
Maxillary second premolar	11.4	11.7
Maxillary first molar	6.1	6
Maxillary second molar	12	12.4
Mandibular central incisor	6.2	6.1
Mandibular lateral incisor	6.9	7.1
Mandibular canine	10	10.7
Mandibular first premolar	10.5	10.7
Mandibular second premolar	11.4	11.6
Mandibular first molar	6	6.1
Mandibular second molar	11.7	12

The first premolar impaction was initially evaluated by observing the tooth axis and its relationship to the occlusal plane. Secondly, its proximity to other teeth and which jaw it occurred in, past two years of the mean eruption times was observed. Thirdly, the impaction, if it existed, was classified according to whether it was soft tissue or bony.

The distribution (affected jaw – mandible or maxilla and affected side) of tooth impaction was recorded by viewing which tooth was impacted. The affected side (left or right) was also recorded in the data collection form.

2.8 Data capturing

The PI captured patient information on data collection sheets from the patient's records. The data was then recorded in a spreadsheet using Microsoft Office Excel. The information included the patient's unique number, age, gender, the presence of tooth impaction or not, impacted tooth name, affected jaw, affected side and the impaction classifications according to Pell and Gregory, Winter, Yamamoto, whether soft or bony and Smailiene's positioning.

2.9 Data analysis

A summary of the study objectives and data analysis performed is shown in Table 2.1.

Table 2.2 Overview of study objectives and data analysis

Objective	Data analysis
1. To determine the prevalence of impacted teeth from pre-treatment panoramic radiographs of orthodontic patients presenting at the Orthodontic Clinic of the WOHC.	Frequencies and percentages were used to describe the prevalence of impacted teeth from pre-treatment panoramic radiographs of orthodontic patients. We calculated the prevalence by expressing the number of patients' records with one or more impacted teeth (113) as a percentage of the total sample (323).
2. To classify the type and distribution of impacted teeth from pre-treatment panoramic radiographs.	Frequency distribution: count and percentages of impacted teeth by type, site, gender and age.
3. To assess the distribution of impacted teeth between the two jaws	Descriptive (frequencies, mean, median, and standard deviation)
4. To explore the association between the type of impaction and the affected jaw	The Chi-square test was used to determine the statistical association between the affected side and jaw regarding impacted teeth. P values of less than .05($p<.05$) were considered statistically significant.
5. To analyse the association between age and gender, and between gender, age, and affected sides regarding impacted teeth.	The Chi-square test was used to determine the statistical association between gender, age, and affected side regarding impacted teeth. P values of less than .05($p<.05$) were considered statistically significant.

2.10 Ethical considerations

A study proposal was presented to the Faculty of Health Sciences, and an application for the study title was made. Subsequently, the study title was approved (Appendix B). The Wits Human Research Ethics Committee (Medical) - HREC granted ethical approval for the study, and the study was allocated No: **M220921** (Appendix C). Permission to conduct the study and access patient records was obtained from the School of Oral Health Sciences, Faculty of Health Sciences, University of the Witwatersrand and WOHC Research and Risk Committee, and the allocated reference number is HRRC/December/11/2022 (Appendix D).

This study adhered to strict confidentiality protocols, utilising anonymous sample identification numbers and excluding all personally identifiable information, including names and surnames.

Chapter 3: Results

A total of 1,327 patients were seen at the Orthodontic Clinic at WOHC between 1 January 2015 and 31 December 2019. Of these, 323 patients' records met the inclusion criteria. Figure 3.1 shows the distribution of the impacted teeth. Out of the 323 panoramic radiographs, 113 had at least one impacted tooth. The prevalence of impaction was 35.0 %.

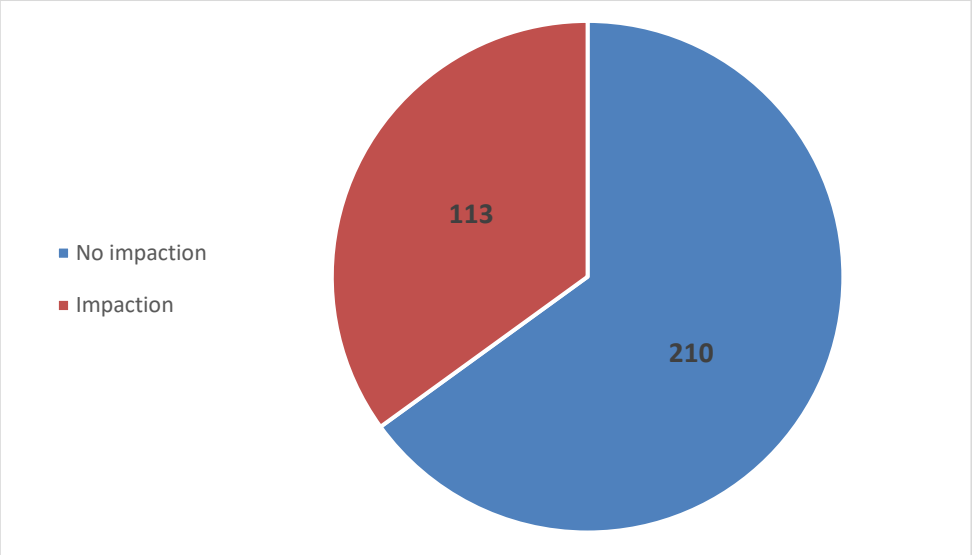


Figure 3.1 Prevalence of impacted teeth

The age range of the participants was 6-53 years. The median age was 12 years, with an Interquartile range (IQR) of 9-18 years. The study samples were placed into age categories. The distribution of tooth impaction in different age groups and genders (Table 3.1) showed that the 6-12-year age group had the most impactions, accounting for 32.7%. There were 64 (56.6%) males and 49 (43.4%) females with impacted teeth.

Table 3.1 Demographic data

Variable	Categories(age)	No impaction n(%)	Tooth impaction n(%)	Total n(%)
Age	6-12 years	144(68.6)	37(32.7)	181(56.0)
	13-18 years	35(16.7)	35(31.0)	70(22.7)
	19-29 years	24(11.2)	35(31.0)	59(18.3)
	30-40 years	5(2.4)	5(3.5)	10(3.1)
	41+ years	2(1.0)	1	3(0.9)
Total		210(65.0)	113(35.0)	323(100)
Gender	Female	91(43.3)	49(43.4)	140(43.3)
	Male	119(56.7)	64(56.6)	183(56.7)
Total		210	113	323

The frequency of impacted teeth per person is shown in Figure 3.2. The total number of impacted teeth was 251 in 113 patients. For those who had impacted teeth, the distribution of impacted teeth was as follows: 38.1%(n=43) presented with single impactions, 34.5%(n=39) with dual impactions, 10.6%(n=12) with triple impactions, and 9.7%(n=11) with quadruple impactions. A smaller subset of individuals exhibited five (2.7%, n=3) or six (2.7%, n=3) impactions while 0.9%(n=1) each with seven and ten impactions. Notably, no instances of eight or nine concurrent impactions were observed. Of the 323 reviewed records, 11.1% (n=36) had at least one impacted third molar. There were nine records (2.8%) with single third molar impaction, 10(3.1%) with two impacted third molars, 2.2 % (n=7) with three-third molar impaction and ten (3.1%) with all four impacted third molars. Mandibular third molars accounted for 54.4% of third molar impaction.

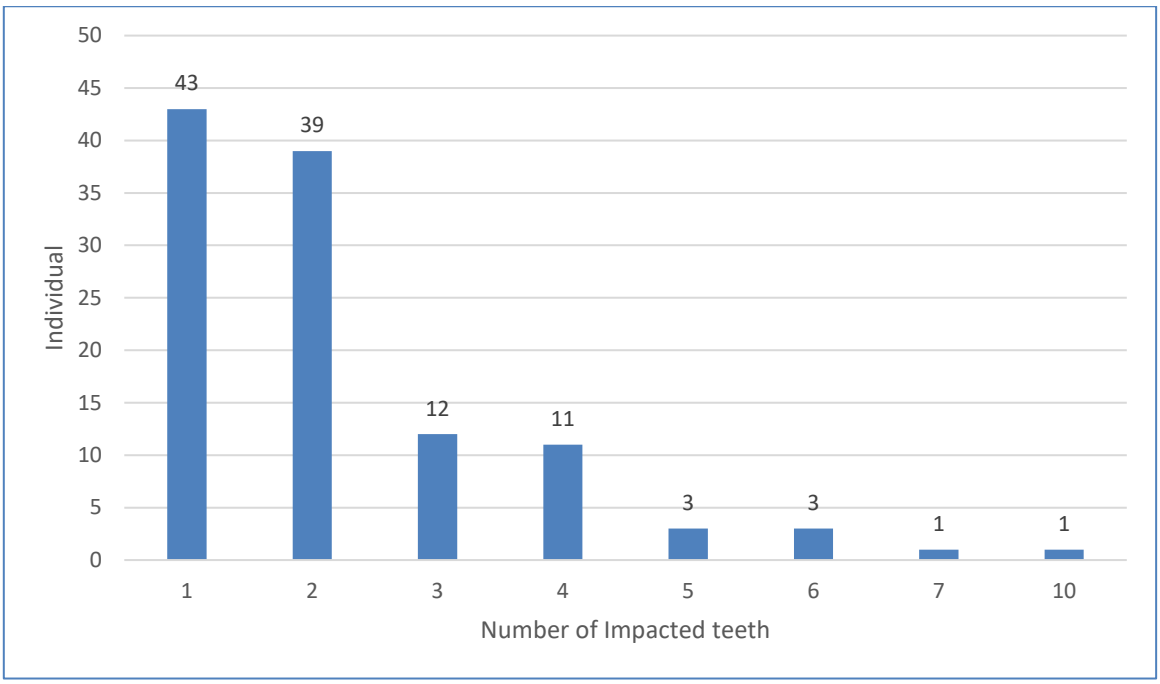


Figure 3.2 The distribution of impacted teeth per individual

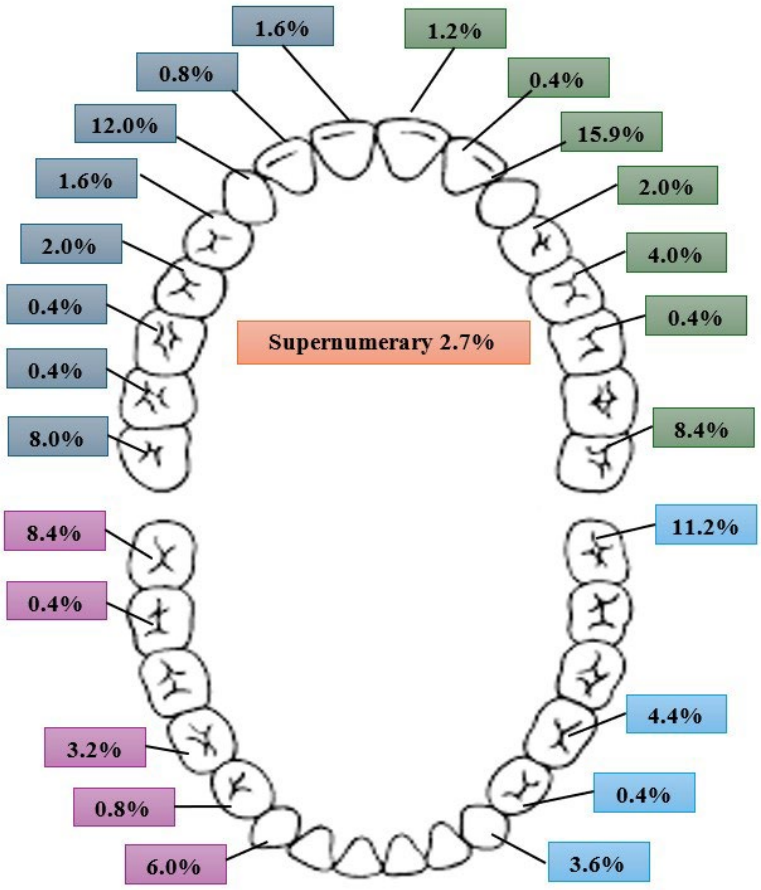


Figure 3.3 Frequency of impacted teeth

Figure 3.3 shows the frequency of impacted teeth. The most frequently impacted tooth was the left maxillary canine (tooth 23) at 15.9%, followed by the right maxillary canine (tooth 13) at 12.0%, and the left mandibular third molar (tooth 38) at 11.2%.

The panoramic radiographs of 113 patients revealed that there were 251 impacted teeth. Table 3.2 provides a comprehensive overview of impacted teeth distribution among the 113 patients. Maxillary canines were the most commonly impacted teeth, accounting for 27.9% (n=70) of all impactions. The third mandibular molar followed, with 19.5% (n=49). In the maxilla, canines were the most impacted teeth (n=70), followed by third maxillary molars (n=41), second premolars (n=15), incisors (n=10) and supernumerary teeth (n=7). In the mandible, the third mandibular molars were the most commonly impacted teeth (n=49), representing 54.4% of all third molar impaction. Canine (n=24) and second premolars (n=19) were also impacted, accounting for 55.9% of all second premolar impaction. Incisors (n=10) and supernumerary (n=7) impaction were exclusive to the maxilla. Maxillary impactions are more common (61.8%), and left-sided impactions are slightly more prevalent (53.4%)

Table 3.2 Distribution of impacted teeth by jaw and side

	Upper		Lower		Right		Left	
	Teeth number	**n (%)**	**Teeth number**	**n (%)**	**Teeth number**	**n (%)**	**Teeth number**	**n (%)**
3rd molars	18,28	41(45.6%)	38,48	49(54.4%)	18,48	41(45.6%)	28,38	49(54.4%)
2nd molars	17,27	1	37,47	1	17.47	2	27,37	0
1st molars	16,26	2	36,46	0	16,46	1	26,36	1
2nd premolars	15,25	15(44.1%)	35,45	19(55.9%)	15,45	13(38.2%)	25,35	21(61.8%)
1st premolars	14,24	9(75.0%)	34,44	3(25%)	14,44	6(50%)	24,34	6(50%)
Canines	13,23	70(74.5%)	33,43	24(25.5%)	13,43	45(47.9%)	23,33	49(52.1%)
Lateral incisors	12,22	3(100%)	32,42	0	12,42	2(66.7%)	22,32	1(33.3%)
Central incisors	11,21	7(100%)	31,41	0	11,41	4(57.1%)	21,31	3(42.9%)
Supernumerary		7(100%)		0		3(42.9%)		4(57.1%)

Table 3.3 shows the distribution of maxillary canine impaction. Maxillary canine impaction accounted for 27.9% of all tooth impaction and 74.5% of canine impaction. The left maxillary canine was the most frequently impacted tooth (15.9%). The highest proportion of impacted maxillary canines classified according to Yamamoto and co-workers [26] was Type I (51.4%), followed by Type VII (27.1%), Type II(15.7%), Type IV(4.3%) and Type III(1.4%). Gender distribution was predominantly even (51.4% female, 48.6% male). No cases of Type V and VI were recorded.

Table 3.3 Maxillary canine impaction according to Yamamoto classification

Type	Localisation		Gender		Total	
	Right '13'	Left '23'	Female	Male	n	%
Type I	17	19	19	17	36	**51.4**
Type II	5	6	7	4	11	**15.7**
Type III	0	1	1	0	1	**1.4**
Type IV	1	2	2	1	3	**4.3**
Type VII	7	12	7	12	19	**27.1**
Total n (%)	**30**	**40**	**36**	**34**	**70**	**100**

Table 3.4 below shows the distribution of third molar impaction according to Winter's classification.[24] In the maxilla, the most common type of impaction was vertical angulation, 61.0% (n=25), followed by *disto*-angular angulation, 31.7% (n=13). *Mesio*-angular angulation, 7.3% (n=3), was the maxilla's most minor common type of impaction angulation. In the mandible, *mesio*-angular angulation accounted for 55.1% (n=27), followed by vertical angulation, 22.4% (n=11) and horizontal angulation, 12.2% (n=5). Four cases (8.2%) of inverted impacted mandibular third molars and one molar had its crown facing buccally.

Table 3.4 The distribution of molar impaction

Winter's classification	Maxillary third molar n (%)	Mandibular third molar n (%)	Females n(%)	Males n(%	Total n (%)
***Mesio*-angular**	3 (7.3%)	27 (55.1%)	14 (46.7%)	16 (53.3%)	30 (33.3%)
***Disto*-angular**	13 (31.7%)	0	9 (69.2%)	4 (30.8%)	13 (14.4%)
Vertical	25 (61.0%)	11 (22.4%)	13 (36.1%)	23 (63.9%)	36 (40.0%)
Horizontal	0	6 (12.2%)	0	6 (100%)	6 (6.7%)
Inverted	0	4 (9.8%)	2 (50.0%)	2 (50.0%)	4 (4.4%)
Bucco-lingual	0	1 (2.4%)	0	1 (100%)	1 (1.1%)

Figure 3.4 illustrates the distribution of mandibular third molar impactions categorised according to Pell and Gregory's classification.[25] The results demonstrate a predominance of Position C Class 3 (3C) impactions, accounting for 30.6 % (n = 15) of the total, followed by 1A and 2B (20.4%, n=10) and Position A Class 2 (2A) comprised 18.4% (n=9) of third mandibular molar impactions. The least common presentation was Position B Class 1 (1B), with 2.1 % (n=1).

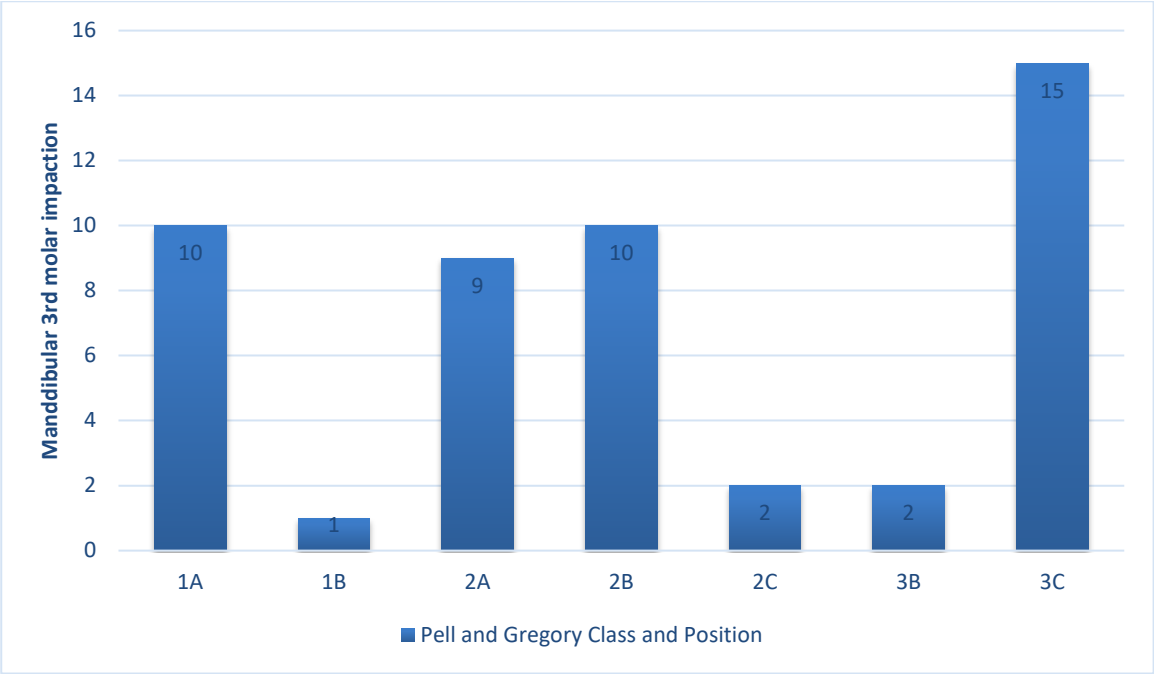


Figure 3.4 The distribution of third molar impaction

Table 3.5 shows the distribution of the impacted second premolar. From the 323 records, 34 (13.5%) of the evaluated records had at least one impacted second premolar. The left side n =21 (61.8%) was more affected, and the mandibular second premolar had a higher frequency of impaction n=19 (55.9%) than the maxillary second premolar. The left mandibular second premolar was the most commonly impacted second premolar, accounting for 32% of second premolar impaction. Males demonstrated a higher susceptibility to impacted second premolars, comprising 56% (n=19) of the cases, whereas females accounted for 44%. Considering Yamamoto's second premolar impaction classification, Type I impactions predominate, accounting for 55.9 % (n=9) of second premolar impactions, followed by Type III, occurring in 29.4 % (n=10). Less frequent second premolar classifications include Type II (5.9%), Type VII (5.8%) and Type IV (2.9%).

Table 3.5 The distribution of impacted second premolars according to location and gender

Type	Localisation				Gender		Total	
	Tooth 15	**Tooth 25**	**Tooth 35**	**Tooth 45**	**Male**	**Female**	**n**	**%**
Type I	1	4	9	5	10	9	19	55.9
Type II	2	0	0	0	2	0	2	5.9
Type III	1	5	1	3	5	5	10	29.4
Type IV	1	0	0	0	1	0	1	2.9
Type VII	0	1	1	0	1	1	2	5.8
Total n (%)	**5(15)**	**10(29)**	**11(32)**	**8(24)**	**19(56)**	**15(44)**	**34**	**100**

Table 3.6 shows the distribution of impacted incisors by position-according to Smailene and co-workers' incisor impaction classification[27], localisation and gender. A total of ten incisor impactions were noted. Males were found to be more predisposed to impacted incisors; nine of the ten incisor impactions were noted in males. Tooth number 11 was the most frequently impacted incisor, 40% (n=4). According to Smailene and co-workers[27], incisor impaction classification, n =5(50%) of the impacted incisors' crowns were coronal or at the gingival third of the root of the contralateral erupted incisor, whilst n =3 (30%) were at V3 and n =2(20%) were at V2. Two cases (20%) were associated with retained primary incisors. A case of a horizontally oriented impacted central incisor in a cleft lip and palate patient.

Table 3.6 The distribution of impacted incisors

Position	Localisation				Gender		Total
	Tooth 11	Tooth 12	Tooth 21	Tooth 22	Male	Female	n
V1	1	1	2	1	4	1	5
V2	2	0	0	0	2	0	2
V3	1	1	1	0	3	0	3
Total (n)	4	2	3	1	9	1	10

The association between genders, age, affected side and affected jaw was evaluated using the Chi-squared test (χ^2 test) and presented in Table 3.7. Males had a higher prevalence of both mandibular (55.7%) and maxillary (58.4%) impactions. Additionally, the right side exhibited a higher frequency of impactions in both the mandible (59%) and maxilla (67.4%). Statistical analysis revealed a significant association between the side and maxillary impactions (P=0.002). Furthermore, age was significantly associated with mandibular impaction (P<0.001), with 52.5% of cases occurring in individuals aged 19 years and older. However, no significant association was found between age group and maxillary impaction (P=0.166).

Table 3.7 Association between gender, affected side, age and jaw regarding impacted teeth

		Mandible			Maxilla		
		No n (%)	Yes n (%)	P- value	No n (%)	Yes n (%)	P-value
Gender	Female	22(42.3)	27(44.3)	0.834	12(50)	37(41.6)	0.460
	Male	30(57.7)	34(55.7)		12(50)	52(58.4)	
Side affected	Left	20(38.5)	25(41)	0.785	16(66.7)	29(32.6)	0.002
	Right	32(61.5)	36(59)		8(33.3)	60(67.4)	
Age groups	6-12	21(40.4)	16(26.2)	<0.001	8(33.3)	29(32.6)	0.166
	13-18	22(42.3)	13(21.3)		4(16.7)	31(34.8)	
	≥19	9(17.3)	32(52.46)		12(50)	29(32.6)	
Total		52(46)	61(54)		24(21.2)	89(78.8)	

Chapter 4: Discussion

This retrospective study of panoramic radiographs showed that the prevalence of impacted teeth was 35.0% in South African patients who attended the WOHC Orthodontic clinic. Panoramic radiographs, a 2D imaging modality, have been a cornerstone in oral diagnostics for more than half a century, aiding in detecting and evaluating oral pathologies and abnormalities.[88] Despite inherent limitations, notably image distortion and superimposition, panoramic radiography remains a fundamental diagnostic tool in dentistry, particularly orthodontics. This imaging modality facilitates a comprehensive orthodontic diagnosis, assessment of dental anomalies like tooth agenesis and impactions and evaluation of root angulations. It also guides optimal root positioning and orthodontic treatment planning, ensuring effective care.[89] The use of panoramic radiography to study impacted teeth is widely utilised due to the relatively low cost of such an investigation.

This study found that the maxillary canines exhibited the highest impaction frequency among orthodontic patients, followed by mandibular third molars, then maxillary third molars, mandibular canines, mandibular second premolars and maxillary second premolars. First premolar impaction was also recorded, with the maxilla mostly affected. There was also appreciable incisor and supernumerary teeth impaction. First and second molar impaction had the least frequency, with only one patient having bilateral maxillary first molar impaction.

The proportion of impacted teeth in the current study falls within the range of the previous studies, which reported the prevalence ranged from 8.3 % to 44.1%.[4, 6, 13, 20, 21, 38] as shown in Table 4.1. Notably, a study at Taibah University, Saudi Arabia, found a significantly lower prevalence of 2.5%.[11] The variability in reported prevalences across studies likely stems from differences in diagnostic criteria and study population characteristics, including demographics and sample sizes.

Table 4.1 Prevalence of tooth impaction

Author, Year	Region	Impacted teeth(n)	Prevalence of impaction (%)	Third molar impaction n (%)
Kramer and Williams, 1970	USA, North America	1218	18.3	1146 (94.1%)
Ahlqwist and Grondahl,1991	Sweden, Europe	166	8.3	141 (84.9%)
Chu *et al*, 2003	China, Asia	3853	28.3	3778 (98.1%)
Al-Ramil *et al.*, 2018	Saudi Arabia, Asia.	355	27.1	332 (93.5%)
Zraiki and Kaseeh, 2018	Syria, Asia.	755	21.6	700 (92.7%)
Chikanga *et al,* 2025	Johannesburg, South Africa	251	35	90(35.9%)

Source: [4-6, 13, 21]

In orthodontics, canine impaction is of great importance due to its enormous contribution to the development of malocclusion and aesthetic discrepancies. As such, many studies have focused on the prevalence of canine impaction and, more significantly, the maxillary canine impaction.[6, 17, 29, 34, 80, 90] In 2019, Alyami and co-workers studied a sample of 2000 panoramic radiographs of Saudi patients and reported that 107 records (5.4%) had at least one impacted canine. Of these, 99 (92.5%) were in the maxilla.[90] Gashi and co-workers examined 810 records of patients treated at the University of Dentistry in Kosovo and found 1.6% of patients with impacted canines.[17] The current study in a teaching hospital orthodontic clinic reported a canine impaction prevalence of 17.3%. This finding is out of the 1.6%-5.4% prevalence range recorded from previous studies.[17, 21, 22, 90] The disparity in prevalence rates may be attributed to the current study's focus on orthodontic patients, who are more likely to be referred to the clinic due to the presence of canine impaction, thereby potentially inflating the observed prevalence. Our study findings showed that the maxillary canines had the highest impaction prevalence of 27.9%, representing 74.5% of canine impaction. Similar results were reported by Yemitan in Nigeria, who also found that the maxillary canines were more frequently impacted than mandibular canines.[18] These qualitative similarities suggest that the findings from this current study are consistent with those of Yemitan's study, providing evidence of a common trend in canine impaction patterns.

The literature has reported that unilateral canine impaction is more common than bilateral impaction [34, 90] and similarly, this study found that unilateral maxillary canine impaction was more common. Consistent with prior research, our study found that unilateral canine impaction was more common on the left side, corroborating findings from other studies.[10, 11, 89, 90]

The current study found that the Yamamoto Type I canine impaction had the highest frequency (Table 3.3). This finding aligns with Yamamoto and co-workers' research, which identified Type I as the most common. However, our results differed from Yamamoto and co-workers regarding the second most common type, since Type VII ranked second, followed by Type II. In contrast, Yamamoto and co-workers reported that Type I was followed by Type II (34.3%) as the second most common, followed by Type IV (11.5%).[26] The differences could be due to differences in sampling methods. The current study sample was drawn from general orthodontic patients. In contrast, the study sample in Yamamoto and co-workers' research was drawn from patients who had already been diagnosed with canine impaction.

Third molar impaction affects a significant portion of the global population, with reported prevalence rates varying between 17% and 81.0%.[19, 91-93] The present study found a prevalence of 11.1%, which is lower than the reported prevalence from previous studies.[19, 91-93] This discrepancy may be attributed to differences in sample demographics and the inclusion of younger patients in the study population. This study found that impacted third molars were more common in the mandible, with a prevalence of 54.4%, compared to 45.6% in the maxilla. The left side had more third molar impaction (54.6%) than the right. These findings from the current study show a similar pattern to those of previous studies[6, 19] reported that the mandibular third molars were the most frequently impacted third molars. However, our findings differ from those reported by Kramer and Williams[21], who found that maxillary third molar impactions accounted for 62.6% of third molar impactions. These discrepancies may stem from variations in geographic locations and sample demographics; Kramer and Williams' study drew their study from patients who attended the oral and maxillofacial clinics and were likely to present with complicated maxillofacial cases.

The extent of third molar impaction is evaluated based on angular position and bone depth, with Winter's classification providing a standardised framework.[24] Notably, this investigation revealed that mesio-angular impaction was the most common type of third mandibular molar impaction, followed by vertical and horizontal. The findings from this study concurred with the findings from previous investigations that reported that *mesio*-angular impaction was the most prevalent.[19, 91, 92, 94] A discrepancy was observed between this study's findings and those of a report, which documented vertical impaction as the most prevalent pattern. [95] Ethnicity factors may contribute to this difference;

the sample for the previous study was drawn from a predominantly Asian population, whereas the sample for this current study was a diverse South African population.

When looking at third maxillary molar impaction exclusively according to Winter's classification, vertical impaction was recorded most frequently (61.0%). This finding from the current study agrees with the results recorded in the literature.[19, 93, 96] In contrast, Khouri and co-workers recorded disto-angular angulation as the most common in third maxillary molar impaction in a Lebanese population.[97] The current study recorded that disto-angular impaction was the second most frequent. This finding from the current study agrees with Hassan and co-workers on a Western Saudi population, where they found that vertical impaction was the most common third molar impaction (49.6%), followed by distal impaction (25.4%).[93]

The current study applied Pell and Gregory classification [70] to impacted third mandibular molars and found that Position A was the most frequent, followed by Position C and then Position B. This order of frequency is consistent with previous findings.[98] In terms of the classification levels, (C1, C2, and C3), this study found that C2 and C3 were the most frequent, while C1 was the least frequent. However, this contradicts a previous report by Ali and co-workers, which showed that C 1 was the most frequent, followed by C 2 and then C 3.[98] Majority of impacted third molars in this study presented with Class 3 Position C followed by Class 1 Position A and Class 2 Position B. Notably, certain combinations, such as Class 3 Position A and Class 1 Position C were not observed. These findings differ from those reported in previous studies, which identified different combinations as the most frequent. Alsadart and co-workers and Santos and co-workers who reported the most frequent Pell and Gregory level and position were Class 2 Position A and Class 2 Position B.[99, 100]

Premolar impaction, particularly second premolar impaction, is commonly diagnosed in dental practice.[82] The overall prevalence of premolar impaction in the current study was 8%, and these results are inconsistent with the literature, which reports a prevalence of between 2.1% and 2.7%.[21, 87] Consistent with Yamamoto et al.'s findings, Type I second premolar impaction exhibited the highest frequency in the current study.[26] Type III second premolar impaction had the second highest frequency, followed by Type II. This finding was, however, in contradiction with the results from the Yamamoto and co-workers' study, which recorded Type II as the second most common, followed by Type III.[26]

Contrary to a previous report indicating similar prevalence rates for maxillary incisors and canine impaction, our study reveals a distinct disparity.[42] In the current study, the prevalence of impacted incisors was 2.5%, with all cases in the maxilla. Specifically, central incisors comprised 70% of impacted incisors, with over half occurring on the right side. Males (90%) were affected more than

females. These findings differ significantly from those reported by Kafle and co-workers, who reported a 1.4% and 1.8% incisor impaction prevalence at two centres in a Nepalese orthodontic clinic patient population.[16] The study conducted by Topkara and co-workers documented an incisor impaction prevalence of 0.65%, a rate that diverges considerably from our research findings.[41]

The prevalence of impacted supernumerary teeth in the current study was 1.5%, and is within the range of reported prevalences of between 0.1 and 3.8%.[34, 89] This result was much lower than the 6.7% prevalence rate reported in a study on 19th-century skeletal remains in South Africa.[101] Differences in sampling methods, participant age, diagnostic criteria, geographic location and ethnic background can explain the observed differences in prevalence rates between the current and previous study.[101] In the current study, all (n=7) of the impacted supernumerary teeth were located in the maxilla, six of which were found in the molar region. More than half (n=4) of the impacted supernumerary teeth were embedded fully in bone, and the remainder were found in soft tissue. The maxillary left side had the highest frequency of supernumerary teeth impaction (57.1%). These findings from the current study were contrary to findings from a Turkish survey of 2599 patients' panoramic radiographs that reported 67.0% of the supernumerary teeth were found in the premaxilla, with 3.6% of supernumerary teeth being found in the mandible.[45] Most impacted supernumerary teeth are asymptomatic and can only be diagnosed incidentally during radiographic examination. Radiographic examination, particularly panoramic radiography, is essential for early diagnosis of supernumerary teeth.[44]

The current study found that 0.9% (n=3) of the records had impacted molars (first and second), and second molars accounted for 0.6% (n=2). These findings align with previous research indicating that second molar impactions are more common than first molar impactions.[22, 41, 57] The prevalence rate is comparable to that of Fardi and co-workers' study, which reported a 1% molar impaction prevalence.[34]

Strengths

The strengths of the current retrospective study include using a well-defined methodology. There were explicit inclusion and exclusion criteria. A precise pre-analysis calibration was conducted for the PI under supervision. This calibration process was further strengthened by achieving high inter- and intra-observer agreement, thereby enhancing the reliability of the data. Additionally, utilising existing records facilitated efficient data collection while minimising participant burden. During data collection, we confirmed the radiographic findings using the pre-treatment clinical records of each patient. Notably, straightforward statistical analysis was employed to yield meaningful results. This investigation is among the pioneering studies to report the prevalence of tooth impaction across all

tooth groups in a South African patient cohort. Although numerous prevalence studies have been conducted within the South African population, this study uniquely provides a comprehensive assessment of impacted teeth across all tooth groups within a single investigation. The clinical relevance of the present study is to determine the prevalence of impacted teeth in a specific group of patients. We generated comparative data (Table 4.1), which will facilitate the timely detection of impacted teeth and aid in executing the optimum treatment plans for patients.

Limitations

The limitation of the current study was its retrospective design, which may have introduced biases in data collection. However, using multiple data sources and a standardised data collection tool has mitigated the issue of bias. Furthermore, the results of our study cannot be generalised since we used a hospital-based sample of patients referred for specialised care.

Chapter 5: Conclusions

The current retrospective study highlights the significance of tooth impaction in orthodontic patients. The prevalence of tooth impaction was 35.0%, with canines, particularly maxillary canines and mandibular third molars, being frequently affected. Notably, females demonstrated higher tooth impaction rates than males in both the maxilla and the mandible. Age was significantly associated with the jaw in which tooth impaction occurred. These findings underscore the importance of routine orthodontic evaluations and prompt intervention to address tooth impaction. The results inform orthodontic treatment planning and provide valuable insights for dental professionals.

Recommendations

- The clinician should always be on the lookout for impacted teeth in the orthodontic setting for early detection and appropriate clinical management.
- We recommend that extensive epidemiological research be undertaken to determine the prevalence of impacted teeth within the South African population, owing to existing studies' limited scope and sample sizes.
- We recommend that future studies investigate patient demographics, referral pathways, and geographic locations to inform understanding of potential causal factors.
- Conduct research to evaluate the relationship between impacted teeth and orthodontic treatment outcomes, including total treatment time and patient satisfaction.
- It is evident that tooth impaction is a relatively common phenomenon encountered in the orthodontic setting, and the clinician should be aware of the frequency for early detection and appropriate clinical management.

References

1. Hattab F.N. and Abu Alhaija E.S.J. **Radiographic evaluation of mandibular third molar eruption space**. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1999;**88**(3):285-91.
2. Gündüz K., Açikgöz A. and Egrioglu E. **Radiologic investigation of prevalence, associated pathologies and dental anomalies of non-third molar impacted teeth in Turkish oral patients.** Chinese Journal of Dental Research. 2011;**14**(2):141-6.
3. Campbell J.H. and Nagai M.Y. Pediatric Dentoalveolar Surgery. Oral and Maxillofacial Surgery. Third Edition: Elsevier; 2018. p. 257-74.
4. Ahlqwist M. and Gröndahl H.G. **Prevalence of impacted teeth and associated pathology in middle-aged and older Swedish women**. Community Dentistry and Oral Epidemiology. 1991;**19**(2):116-9.
5. Zraiki S. and Kaseeh F. **Study of the prevalence and distribution of impacted teeth and associated pathologies using digital panoramic image in Syrian coastal area.** International Arab Journal of Dentistry. 2018;**9**(3):101-6.
6. Chu F.C.S., Li T.K.L., Lui V.K.B., Newsone P.R.H., Chow R.L.K. and Cheung L.K. **Prevalence of impacted teeth and associated pathologies-a radiographic study of the Hong Kong Chinese population**. Hong Kong Medical Journal. 2003;**9**(3):158-63.
7. Celikoglu M., Miloglu O. and Kazanci F. **Frequency of Agenesis, Impaction, Angulation, and Related Pathologic Changes of Third Molar Teeth in Orthodontic Patients**. Journal of Oral and Maxillofacial Surgery. 2010;**68**(5):990-5.
8. Hou R., Kong L., Ao J., Liu G., Zhou H., Qin R., et al. **Investigation of Impacted Permanent Teeth Except the Third Molar in Chinese Patients Through an X-Ray Study**. Journal of Oral and Maxillofacial Surgery. 2010;**68**(4):762-7.
9. Becker A. **Orthodontic Treatment of Impacted Teeth**. Fourth Edition: Wiley-Blackwell, New Jersey. 2022.p1-362
10. Duarte B.G., Assis D., Ribeiro-Júnior P. and Gonçales E.S. **Does the Relationship between Retained Mandibular Third Molar and Mandibular Angle Fracture Exist? An Assessment of Three Possible Causes**. Craniomaxillofacial Trauma and Reconstruction. 2012;**5**(3):127-35.
11. Al-Zoubi H., Alharbi A.A., Ferguson D.J. and Zafar M.S. **Frequency of impacted teeth and categorisation of impacted canines: A retrospective radiographic study using orthopantomograms**. European Journal of Dentistry. 2017;**11**(01):117-21.

12. Karjodkar F.R. **Textbook of Dental and Maxillofacial Radiology**. Second Edition: Jaypee Brothers Medical Publishers; New Delhi, India: 2011.p 1-61
13. Al-Ramil A.M., Al-Wosaibi A.M., Bukhary M.T. and Al-Wusaybie M.M. **Prevalence of impacted teeth and associated pathologies – A radiographic study, Al Ahsa, Saudi Arabia population**. The Egyptian Journal of Hospital Medicine. 2018;**70**(12):2130-6.
14. Scarfe W.C., Farman A.G. and Sukovic P. **Clinical applications of cone-beam computed tomography in dental practice**. Journal of the Canadian Dental Association. 2006;**72**(1):75-80.
15. Walker L., Enciso R. and Mah J. **Three-dimensional localisation of maxillary canines with cone-beam computed tomography**. American Journal of Orthodontics and Dentofacial Orthopaedics. 2005;**128**(4):418-23.
16. Kafle D., Shrestha S., Acharya N. and Agarwal A. **Prevalence of Maxillary Central Incisor Impaction and Supernumerary Teeth among Nepalese Orthodontic Patients**. Orthodontic Journal of Nepal. 2015;**5**(2):14-6.
17. Gashi A., Kamberi B., Ademi-Abdyli R., Perjuci F. and Sahatçiu-Gashi A. **The incidence of impacted maxillary canines in a Kosovar population**. International Scholarly Research Notices. 2014;**2014**:1-4.
18. Yemitan T. **Pattern of permanent canine impaction and associated retained deciduous canine of a Nigerian orthodontic patient population**. Annals of Clinical Sciences. 2018;**3**(2):34-8.
19. Ishwarkumar S., Pillay P., Haffajee M. and Satyapal K.S. **Prevalence of impacted third molars in the South African Indian population of the eThekwini Metropolitan Region**. South African Dental Journal. 2019;**74**(6):302-9.
20. Alamri A., Alshahrani N., Al-Madani A., Shahin S. and Nazir M. **Prevalence of Impacted Teeth in Saudi Patients Attending Dental Clinics in the Eastern Province of Saudi Arabia: A Radiographic Retrospective Study**. The Scientific World Journal. 2020;**2020**:1-6.
21. Kramer R.M. and Williams A.C. **The incidence of impacted teeth-A survey at Harlem Hospital.** Oral Surgery, Oral Medicine, Oral Pathology. 1970;**29**(2):237-41.
22. Grover P.S. and Lorton L. **The incidence of unerupted permanent teeth and related clinical cases**. Oral Surgery, Oral Medicine, Oral Pathology. 1985;**59**(4):420-5.
23. Siotou K., Kouskouki M.P., Christopoulou I., Tsolakis A.I. and Tsolakis I.A. **Frequency and Local Etiological Factors of Impaction of Permanent Teeth among 1400 Patients in a Greek Population**. Dentistry Journal. 2022;**10**(8):150.
24. Winter G.B. **Principles of exodontia as applied to the impacted mandibular third molar: A complete treatise on the operative technic with clinical diagnosis and radiographic interpretations.** American Medical Book Company; St.Louis, Mo.1926.p 835.

25. Pell G.J. **Impacted mandibular third molars: classification and modified techniques for removal**. Dental Digest. 1933;**39**:330-8.
26. Yamamoto G., Ohta Y., Tsuda Y., Tanaka A., Nishikawa M. and Inoda H. **A New Classification of Impacted Canines and Second Premolars Using Orthopantomography**. Asian Journal of Oral and Maxillofacial Surgery. 2003;**15**(1):31-7.
27. Smailiene D., Sidlauskas A. and Bucinskiene J. **Impaction of the central maxillary incisor associated with supernumerary teeth: initial position and spontaneous eruption timing**. Stomatologija. 2006;**8**(4):103-7.
28. Chapokas A.R., Almas K. and Schincaglia G.P. **The impacted maxillary canine: a proposed classification for surgical exposure**. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2012;**113**(2):222-8.
29. Mehta S., Vineetha R., Mehta A., Lodha S. and Sreedharan H. **Unusual impaction of mandibular second premolar**. International Journal of Orthodontic Rehabilitation. 2017;**8**(4):147-9.
30. Haney E., Gansky S.A., Lee J.S., Johnson E., Maki K., Miller A.J., et al. **Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines**. American Journal of Orthodontics and Dentofacial Orthopaedics. 2010;**137**(5):590-7.
31. Rajendran R. **Shafer's Textbook of Oral Pathology**: Elsevier, New Delhi, India; 2009. p 60
32. Joshi M. and Kasat V. **Variations in impacted mandibular permanent molars: Report of three rare cases**. Contemporary Clinical Dentistry. 2011;**2**(2):124-6.
33. Mead S.V. **Incidence of impacted teeth**. International Journal of Orthodontia, Oral Surgery and Radiography. 1930;**16**(8):885-90.
34. Fardi A., Kondylidou-Sidira A., Bachour Z., Parisis N. and Tsirlis A. **Incidence of impacted and supernumerary teeth - a radiographic study in a North Greek population**. Medicina Oral ,Patologia Oral y Cirugia Bucal. 2011:56-61.
35. Aitasalo K., Lehtinen R. and Oksala E. **An orthopantomography study of the prevalence of impacted teeth**. International Journal of Oral Surgery. 1972;**1**(3):117-20.
36. Dachi S.F. and Howell F.V. **A survey of 3,874 routine full-mouth radiographs**. Oral Surgery, Oral Medicine, Oral Pathology. 1961;**14**(10):1165-9.
37. Brown L.H., Berkman S., Cohen D., Kaplan A.L. and Rosenberg M. **A radiological study of the frequency and distribution of impacted teeth**. Journal of the Dental Association of South Africa. 1982;**37**(9):627-30.
38. Arabion H., Gholami M., Dehghan H. and Khalife H. **Prevalence of impacted teeth among young adults: a retrospective radiographic study**. Journal of Dental Materials and Techniques. 2017;**6**(3):131-7.

39. Simsek-Kaya G., Melih-Omezli M., Yapici G., Dayi E. and Ertas U. **Prevalence of impacted premolars in a Turkish population and considerations for surgical treatment**. Medicina Oral Patología Oral y Cirugia Bucal. 2011:781-6.
40. Gisakis I.G., Palamidakis F.D., Farmakis E.-T.R., Kamberos G., Kamberos S. **Prevalence of impacted teeth in a Greek population**. Journal of Investigative and Clinical Dentistry. 2011;**2**(2):102-9.
41. Topkara A. and Sari Z. **Impacted teeth in a Turkish orthodontic patient population: prevalence, distribution**. European Journal of Paediatric Dentistry. 2012;**13**:311-6.
42. Bayram M., Ozer M. and Sener I. **Maxillary canine impactions related to impacted central incisors: two case reports**. Journal of Contemporary Dental Practice. 2007;**8**(6):72-81.
43. Salem G. **Prevalence of selected dental anomalies in Saudi children from Gizan region**. Community Dentistry and Oral pidemiology. 1989;**17**(3):162-3.
44. Patil S. and Maheshwari S. **Prevalence of impacted and supernumerary teeth in the North Indian population**. Journal of Clinical and Experimental Dentistry. 2014;**6**(2):116-20.
45. Esenlik E., Sayın M.Ö., Atilla A.O., Özen T., Altun C. and Başak F. **Supernumerary teeth in a Turkish population**. American Journal of Orthodontics and Dentofacial Orthopaedics. 2009;**136**(6):848-52.
46. Roberts-Harry D. and Sandy J. **Orthodontics. Part 10: Impacted teeth**. British Dental Journal. 2004;**196**(6):319-27.
47. Bereket C., Cakir-Ozkan N., Sener I., Kara I., Murat-Aktan A. and Arici N. **Retrospective analysis of impacted first and second permanent molars in the Turkish population: A multicenter study**. Medicina Oral Patología Oral y Cirugia Bucal. 2011:874-8.
48. Mehta D., Mehta M., Murgesh S. and Thakur S. **Bilateral impaction of mandibular second and third molars**. Journal of the Indian Dental Association. 1987;**59**(1):24-.
49. Shapira Y., Borell G., Nahlieli O. and Kuftinec M.M. **Uprighting mesially impacted mandibular permanent second molars**. The Angle Orthodontist. 1998;**68**(2):173-8.
50. García-Calderón M., Torres-Lagares D., González-Martín M. and Gutiérrez-Pérez J.L. **Rescue surgery (surgical repositioning) of impacted lower second molars**. Medicina Oral Patología Oral y Cirugia Bucal. 2005;**10**(5):448-53.
51. Richardson M.E. **The aetiology and prediction of mandibular third molar impaction**. The Angle Orthodontist. 1977;**47**(3):165-72.
52. Carter K. **The evolution of third molar agenesis and impaction**. PhD[Dissertation] Massachusetts, USA. Harvard University. 2016. http://nrs.harvard.edu/urn-3:HUL.InstRepos:33493544.

53. Spiotto M.T., Juodzbalys G. and Daugela P. **Mandibular Third Molar Impaction: Review of Literature and a Proposal of a Classification**. Journal of Oral and Maxillofacial Research. 2013;**4**(2):1-11.
54. Gooris C.G.M., Rtun J. and Joondeph D.R. **Eruption of mandibular third molars after second-molar extractions: A radiographic study**. American Journal of Orthodontics and Dentofacial Orthopaedics. 1990;**98**(2):161-7.
55. Bashir S., Rasool G., Afzal F. and Hassan N. **Incidence of mandibular 3rd molar impactions in different facial types of orthodontic patients seen at Khyber College of Dentistry.** Pakistan Oral and Dental Journal. 2016;**36**(2):232-34.
56. Peck L., Peck S. and Attia Y. **Maxillary canine-first premolar transposition, associated dental anomalies and genetic basis**. The Angle Orthodontist. 1993;**63**(2):99-109.
57. Baccetti T.A. **A controlled study of associated dental anomalies**. The Angle Orthodontist. 1998;**68**:267-74.
58. Pirinen S., Arte S. and Apajalahti S. **Palatal displacement of canine is genetic and related to congenital absence of teeth**. Journal of Dental Research. 1996;**75**(10):1742-6.
59. Peck S., Peck L. and Kataja M. **The palatally displaced canine as a dental anomaly of genetic origin**. The Angle Orthodontist. 1994;**64**(4):250-6.
60. Jacoby H. **The aetiology of maxillary canine impactions**. American Journal of Orthodontics. 1983;**84**(2):125-32.
61. Bishara S.E. and Ortho D. **Impacted maxillary canines: A review**. American Journal of Orthodontics and Dentofacial Orthopaedics. 1992;**101**(2):159-71.
62. Becker A., Smith P., Behar R. **The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids**. The Angle Orthodontist. 1981;**51**(1):24-9.
63. Ferrés-Padró E., Prats-Armengol J. and Ferrés-Amat E. **A descriptive study of 113 unerupted supernumerary teeth in 79 pediatric patients in Barcelona**. Medicina Oral Patología Oral y Cirugia Bucal. 2009;**14**(3):E146-52.
64. Rajab L.D. and Hamdan M.A.M. **Supernumerary teeth: review of the literature and a survey of 152 cases**. International Journal of Paediatric Dentistry. 2002;**12**(4):244-54.
65. De Oliveira Gomes C., Drummond S.N., Jham B.C., Abdo E.N. and Mesquita R.A. **A survey of 460 supernumerary teeth in Brazilian children and adolescents**. International Journal of Paediatric Dentistry. 2008;**18**(2):98-106.
66. Betts A. and Camilleri G.E. **A review of 47 cases of unerupted maxillary incisors**. International Journal of Paediatric Dentistry. 1999;**9**(4):285-92.

67. Chaushu S., Zilberman Y. and Becker A. **Maxillary incisor impaction and its relationship to canine displacement**. American Journal of Orthodontics and Dentofacial Orthopaedics. 2003;**124**(2):144-50.
68. Liu J.K., Hsiao C.K., Chen H.A. and Tsai M.Y. **Orthodontic correction of a mandibular first molar deeply impacted by an odontoma: a case report**. Quintessence International. 1997;**28**(6): p381-5. .
69. Shapira Y., Lai Y., Schonberger S., Shpack N. and Finkelstein T. **Mandibular Second Molar Impaction-Part II: Aetiology and Role of the Third Molar**. Applied Sciences. 2022;**12**(22):1-10.
70. Pell G.J. and Gregory G.T. **Report on a ten-year study of a tooth division technique for the removal of impacted teeth**. American Journal of Orthodontics and Oral Surgery. 1942;**28**(11):660-6.
71. Yavuz M.S., Aras M.H., Büyükkurt M.C. and Tozoglu S. **Impacted mandibular canines**. Journal of Contemporary Dental Practice. 2007;**8**(7):78-85.
72. Mitchell L. and Bennett T. **Supernumerary teeth causing delayed eruption—a retrospective study**. British Journal of Orthodontics. 1992;**19**(1):41-6.
73. Suzuki T., Kosugi K., Suto T., Tobe M., Tabata Y., Yokoo S., et al. **Sustained-release lidocaine sheet for pain following tooth extraction: A randomised, single-blind, dose-response, controlled, clinical study of efficacy and safety**. Public Library of Science 2018;**13**(7):1-19.
74. Archer W.H. **Oral and Maxillofacial Surgery**. Fifth Edition. W.B.Saunders Company; Philadelphia, USA. 1975.
75. Passi D., Singh G., Dutta S., Srivastava D., Chandra L., Mishra S., et al. **Study of pattern and prevalence of mandibular impacted third molar among Delhi-National Capital Region population with newer proposed classification of mandibular impacted third molar: A retrospective study**. National Journal of Maxillofacial Surgery. 2019;**10**(1):59-67.
76. Hamada Y., Timothius C.J.C., Shin D. and John V. **Canine impaction – A review of the prevalence, aetiology, diagnosis and treatment**. Seminars in Orthodontics. 2019;**25**(2):117-23.
77. Kau C., Pan P., Gallerano R. and English J. **A novel 3D classification system for canine impactions - The KPG index**. The International Journal of Medical Robotics and Computer Assisted Surgery. 2009;**5**:291-6.
78. Aljabri M., Aljameel S.S., Min-Allah N., Alhuthayfi J., Alghamdi L., Alduhailan N., et al. **Canine impaction classification from panoramic dental radiographic images using deep learning models**. Informatics in Medicine Unlocked. 2022;**30**:10-8.
79. Proffit W.R., Fields H.W., Larson B., Sarver D.M. **Contemporary Orthodontics - E-Book.** Sixth Edition. Elsevier Health Sciences; Philadelphia, USA 2018. 265-320.

80. Sajnani A.K. and King N.M. **Complications associated with the occurrence and treatment of impacted maxillary canines**. Singapore Dental Journal. 2014;**35**:53-7.
81. Kokich V.G. **Surgical and orthodontic management of impacted maxillary canines**. American Journal of Orthodontics and Dentofacial Orthopaedics. 2004;**126**(3):278-83.
82. McNamara C. and McNamara T.G. **Mandibular premolar impaction: 2 case reports**. Journal of the Canadian Dental Association. 2005;**71**(11):859-63.
83. Collett A.R. **Conservative management of lower second premolar impaction**. Australian Dental Journal. 2000;**45**(4):279-81.
84. Murray P. and Brown N.L. **The conservative approach to managing unerupted lower premolars - two case reports**. International Journal of Paediatric Dentistry. 2003;**13**(3):198-203.
85. Worth H.M. **Principles and Practice of Oral Radiologic Interpretatio**n: Year Book Medical Publishers; Michigan, USA. 1963.
86. Mariano R.C., de Carvalho Freire Mariano L. and de Melo W.M. **Deep impacted mandibular second molar: A case report**. Quintessence International. 2006;**37**(10).
87. Wedl J.S., Danias S., Schmelzle R. and Friedrich R.E. **Eruption times of permanent teeth in children and young adolescents in Athens (Greece)**. Clinical Oral Investigations. 2005;**9**(2):131-4.
88. Pauwels R. **History of dental radiography: Evolution of 2D and 3D imaging modalities**. Medical Physics International 2020;**8**(1):235-77.
89. Thomas E., Oettlé A.C. and Becker P. **Supernumerary teeth in a sample of South African dental patients**. South African Dental Journal. 2023;**78**(2):74-81.
90. Alyami B., Braimah R. and Alharieth S. **Prevalence and pattern of impacted canines in Najran, South Western Saudi Arabian population**. The Saudi Dental Journal. 2020;**32**(6):300-5.
91. Syed K.B., Zaheer K.B., Ibrahim M., Bagi M.A. and Assiri M.A. **Prevalence of Impacted Molar Teeth among Saudi Population in Asir Region, Saudi Arabia - A Retrospective Study of 3 Years**. Journal of International Oral Health. 2013;**5**(1):43-7.
92. Tsabedze V.N. **Prevalence of Impacted Mandibular Third Molar Teeth at Medunsa Oral Health Centre**: Master's [Dissertation] Pretoria, SA.University of Limpopo (Medunsa Campus); 2012.
93. Hassan A. **Pattern of third molar impaction in a Saudi population**. Clinical, Cosmetic and Investigational Dentistry. 2010:109-13.
94. Al-Anqudi S.M., Al-Sudairy S., Al-Hosni A. and Al-Maniri A. **Prevalence and Pattern of Third Molar Impaction: A retrospective study of radiographs in Oman**. Sultan Qaboos University Medical Journal. 2014;**14**(3):388-92.

95. Sasano T., Kuribara N., Iikubo M., Yoshida A., Satoh-Kuiriwada S., Shoji N., et al. **Influence of angular position and degree of impaction of third molars on development of symptoms: long-term follow-up under good oral hygiene conditions**. The Tohoku Journal of Experimental Medicine. 2003;**200**(2):75-83.
96. Lim A.A.T., Wong C.W. and Allen Jr J.C. **Maxillary third molar: patterns of impaction and their relation to oroantral perforation**. Journal of Oral and Maxillofacial Surgery. 2012;**70**(5):1035-9.
97. Khouri C., Aoun G., Khouri C., Saade M., Salameh Z. and Berberi A. **Evaluation of Third Molar Impaction Distribution and Patterns in a Sample of Lebanese Population**. Journal of Maxillofacial and Oral Surgery. 2022;**21**(2):599-607.
98. Ali F.M., Jafar M., Bai P., Dungrani H. and Hassan I. **A study of mandibular third molar impaction audit at outpatient department of oral surgery department of college of dental science, Amargadh district, Bhavnagar, Gujarat**. Journal of International Oral Health. 2016;**8**(7):776-80.
99. Alsadat-Hashemipour M., Tahmasbi-Arashlow M. and Fahimi-Hanzaei F. **Incidence of impacted mandibular and maxillary third molars: A radiographic study in a Southeast Iran population**. Medicina Oral, Patologia Oral y Cirugia Bucal. 2012;**18**(1):140-5.
100. Santos K.K., Lages F.S., Maciel C.A.B., Glória J.C.R. and Douglas-de-Oliveira D.W. **Prevalence of Mandibular Third Molars According to the Pell and Gregory and Winter Classifications**. Journal of Maxillofacial and Oral Surgery. 2022;**21**(2):627-33.
101. van der Merwe A. and Steyn M. **The High Prevalence of Supernumerary Teeth in Skeletal Remains from a 19th Century Mining Community from Kimberley, South Africa**. Health and Demography in Late 19th Century Kimberley. 2010;**64**(4):135.

Appendix A. Data collection form

Section A: Biographic Information

Unique Number…….
Age:……
Gender: …….

Section B: Radiographic Examination

					Classifications										
Tooth	Affected jaw		Affected side		**Pell and Gregory's classification**						**Winter's classification**				
	Mx	Md	Rt	Lt	Position			Class			Mesio-angular	Disto-angular	Vertical	Horizontal	Other
					A	B	C	1	2	3					
18															
28															
38															
48															
17															
27															
37															
47															
16															
26															
36															
46															

					Yamamoto *et al.* classification (types)						
					1	2	3	4	5	6	7
13											
15											
23											
25											
33											
35											
43											
45											

					Smailiene *et al.* incisor impaction positioning		
					V1	V2	V3
11							
12							
21							
22							
31							
32							
41							
42							

					Soft tissue impaction	**Bony impaction**
14						
24						
34						
44						
Supernumerary						

Appendix B. Study title approval

10 November 2022
Person No: 315800
PAG

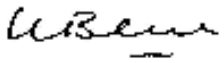
Dr M Chikanga
P.o Box A295
Buhleni
Swaziland
0000
Swaziland

Dear Dr Mollyn Chikanga

Master of Science in Dentistry: Approval of Title

We have pleasure in advising that your proposal entitled *Prevalence of impacted teeth at a Dental School Orthodontic Clinic, Johannesburg, South Africa* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely



Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix C. Ethics clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R49 Dr M Chikanga

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M220921

NAME: (Principal Investigator)	Dr M Chikanga
DEPARTMENT:	School of Oral Health Sciences Department of Orthodontics Dental School University
PROJECT TITLE:	*Prevalence of impacted teeth at a dental school orthodontic clinic, Johannesburg, South Africa*
DATE CONSIDERED:	2022/09/30
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:	Professor P I Ilonga and Dr V Bomvana
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2023/01/20

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 funder 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 **September** and therefore reports and re-certification will be due in the month of **September** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator — Date: 24/01/2023

Appendix D. Permission to collect data

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

School of Oral Health Science

Department of Oral Biological Sciences, 7 York Road, Parktown, 2193. Tel: 011 717 2110 Email: mervyn.turton@wits.ac.za

13 December 2022

Dr M. Chikanga
Orthodontics Department
Faculty of Health Sciences
University of the Witwatersrand
Johannesburg

RE: PERMISSION TO CONDUCT RESEARCH

REFERENCE: HRRC/December/11/2022

It is my pleasure to grant final approval to conduct your research at Wits Oral Health Centre titled "Prevalence of impacted teeth at a Dental School Orthodontic Clinic, Johannesburg, South Africa".

The Hospital Research and Risk Committee allocated a unique reference number to this application – Kindly quote this reference number in all future correspondence regarding this research.

Please note that the Hospital Research and Risk Committee should be informed of the estimated date the research will commence, as well as regular status reports until the research has been concluded. Within a month after conclusion of the research project, a written report must be submitted to the Head of School/CEO, summarizing the final result/outcome as well as the recommendations made based on the research concluded.

Regards,

Joy Shackleton

Acting HOS – Prof J. Shackleton

Date: 13-12-2022

Appendix E. Turnitin report

Mollyn Chikanga

PREVALENCE OF IMPACTED TEETH AT A DENTAL SCHOOL ORTHODONTIC CLINIC, JOHANNESBURG ,SOUTH AFRICA

Dissertation
MSc Dentistry/ Orthodontics
Midlands State University

Document Details

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