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Correlation of age to classification of vertical relationship of maxillary sinus and maxillary first molar root by cone-beam computed tomography: a cross-sectional study

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ABSTRACT

Objectives: The maxillary first molar has a close relationship with the base of the maxillary sinus floor. Cone-beam Computed Tomography (CBCT) provides coronal, sagittal, occlusal, and 3D sectional images of maxillofacial structures without causing distortion. Thus, CBCT allows for a comprehensive analysis of the position of the maxillary first molar about the maxillary sinus. This study aims to determine the correlation between age and the classification of vertical relationship between the maxillary sinus and the roots of the maxillary first molar using CBCT.

Materials and Methods: The research design was the analytical observational research used a cross-sectional design. The study population includes all CBCT radiographs from patients aged 20-50 years who used CBCT at RSGMP Universitas Jenderal Achmad Yani. The total sampling technique was used to include all CBCT radiograph data comforms to the inclusion and exclusion criteria.

Results: The study resulted in 60 CBCT radiographs, with 54 data for the right maxillary first molar and 49 data for the left maxillary first molar. Data analysis using Spearman correlation test showed r = -0.191 with a p-value of 0.166 for the right maxillary first molar and r = -0.167 with a p-value of 0.252 for the left maxillary first molar.

Conclusion: There was no correlation between age and the classification of vertical relationship between the maxillary sinus and the maxillary first molar tooth root (p > 0.05). This is because the volume of the maxillary sinus decreases with age, leading to an increased distance between the maxillary sinus and the tooth roots.

Keywords: *Cone-beam computed tomography, maxillary first molar, maxillary sinus, vertical relationship*
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INTRODUCTION

The maxillary sinus also known as the antrum highmore is an air space located within the human maxillary bone and is associated with the nasal meatus media on the same side.[1,2] Anatomically, the maxillary sinus is one of the largest paranasal sinuses having a pyramid-like shape, and can vary in size and shape between individuals as well as between the right and left sides.[3,4] The growth process of the maxillary sinus begins in the third month of intrauterine life and reaches complete growth around the age of 20, coinciding with the eruption of all permanent teeth.[5,6] However, when this sinus grows larger than normal, it can result in the roots of molar and premolar teeth becoming closer to the maxillary sinus.[5]

Periapical or periodontal infection of the teeth can lead to odontogenic sinusitis which is one of the common problems associated with the maxillary sinus.[7] Dental treatment involving procedures such as tooth extraction can result in complications related to the relationship between the tooth root tip and the maxillary sinus floor such as root tip fracture, oroantral communication, and root displacement in the maxillary sinus.[8] Some studies have also stated that after tooth extraction, there is an increase in maxillary sinus dimensions and pneumatization, while alveolar bone height and width decrease.[9] Previous studies have shown that odontogenic sinusitis originating from dental infections is one of the common problems associated with the maxillary sinus.[10] Various studies have also identified that the maxillary first molar is the tooth that most often causes abnormalities in the maxillary sinus.[11]

Evaluation of the position of posterior tooth roots with the maxillary sinus is important in diagnosis, dental treatment planning, and prognosis to avoid complications.[8,12] Supporting examinations such as intraoral and extraoral radiographs, including Cone-beam Computed Tomography (CBCT) are used to see the position of molar tooth roots against the maxillary sinus in more detail.[4] The study conducted by Chan Po-Sheng et al. examined patients aged 20 years because the maxillary sinus had developed and grown completely.[13] Previous research conducted by Carlos on the vertical position of the maxillary sinus with maxillary first molar and second molar roots using the Kwak classification with CBCT radiographs showed that type II was most common.[14] In contrast, Tuba Talo Yildirim et al. showed that type I was most common in the first molar.[15] Differences in results between studies can be caused by differences in methodology, but are also influenced by ethnic characteristics due to diverse populations.[14] Based on the background description above, the authors would like to conduct research related to the correlation of age to the classification of the vertical relationship of the maxillary sinus and the roots of the maxillary first molar teeth through CBCT at RSGMP Unjani. This research is expected to provide a deeper understanding of the age factor in the relationship between these anatomical structures, as well as assist in planning more appropriate dental treatment. This study aims to determine the correlation of age with the classification of the vertical relationship of the maxillary sinus and the roots of the maxillary first molar teeth through CBCT at RSGMP Unjani.

MATERIALS AND METHODS

This research was conducted at the Radiology Installation of Dentistry, Unjani Dental and Oral Education Hospital. The research was conducted from October to December 2023. Ethical approval was obtained through an approval letter from the Ethics Commission of the Faculty of Medicine, Padjajaran University with letter number 1282/ UN6.KEP/EC/2023.

This study used analytic research with cross sectional method. The research sample consisted of CBCT radiographs taken from 2021 to 2023 in patients aged 20-50 years at RSGMP Unjani Cimahi City.The inclusion criteria in this study include patients who have undergone CBCT radiographic examinations at RSGMP Universitas Jenderal Achmad Yani with an age range between 20 to 50 years, and have complete maxillary first molar teeth. The first molar teeth must be fully erupted with well-formed roots. In addition, patients who became research subjects did not use orthodontic devices. Meanwhile, the exclusion criteria were maxillary first molar teeth with unformed apices, root resorption or fracture, shape anomalies, and periapical or periradicular lesions.

This study determined the sample size using the correlative analytic formula, which resulted in a minimum of 31 samples. In its implementation, the total sampling technique was used, which is a sampling technique where the number of samples is equal to the total population of all CBCT radiograph data including inclusion and exclusion criteria available at RSGMP Unjani used for this research sample. The independent variable in this study was age, which was measured on an ordinal scale, while the dependent variable was the classification of the vertical relationship between the maxillary sinus and the maxillary first molar tooth root, which was also measured on an ordinal scale. The study procedure involved analyzing CBCT radiographs in coronal sections. CBCT radiographs were obtained using a CBCT scanner (Soredex Cranex 3Dx) with parameters of 90 kVp, 4 mA, a voxel size of 0.136 mm^3, and a field of view of 4x6 cm^2 or 6x8 cm^2.

The vertical relationship between the maxillary sinus and the maxillary first molar root was assessed based on the classification made by Kwak et al. The data obtained were recorded in tables using Microsoft Excel, and then statistically analyzed using SPSS software. Data analysis included univariate and bivariate analysis. Univariate data analysis aims to determine the classification of the vertical relationship between the maxillary sinus and the maxillary first molar tooth root. This univariate data was then categorized for the purposes of bivariate analysis using the Spearman correlation test, in order to determine the relationship between age and the classification of vertical relationships of the maxillary sinus and maxillary first molar tooth roots on CBCT radiographs at RSGMP Unjani.

RESULTS

Based on Table 1, it shows that the largest sample of research at RSGMP Unjani in 2021-2023 was in the 31-40 year age category, namely 24 people (40%), 21 people (35%) were in the 20-30 year age category and 15 people (25%) were in the 41-50 year age category. Most of the patients in Unjani RSGMP were female, as many as 61.7%, while male patients were 38.3%. Patient characteristics based on age were obtained in 60 medical records and grouped into 20-30 years, 31-

Table 1. Characteristics of patients based on age and gender

		n	%
Age (year)	20-30 year	21	35%
	31-40 year	24	40%
	41-50 year	15	25%
Gender	Female	23	38,3%
	Male	37	61,7%

Table 2. Overview of age ranges with ingrown maxillary first molar roots in the maxillary sinus

	Age	No entry into the maxillary sinus	Entry into the maxillary sinus
Right	20-30 year	4 (20%)	16 (80%)
	31-40 year	2 (8,3%)	22 (91,7%)
	41-50 year	6 (60%)	4(40%)
Left	20-30 year	4 (22,2%)	14 (77,8%)
	31-40 year	1 (40%)	20 (95,2%)
	41-50 year	4 (18,4%)	6 (60%)

Table 3. Classification of vertical relationship of maxillary sinus and root of maxillary first molar teeth

	Right maxillary first molar		Left maxillary first molar		Total
	Total (n)	Percentage (%)	Total (n)	Percentage (%)	
Type I	4	7,4	3	6,1	7
Type II	8	14,8	6	12,2	14
Type III	7	13	4	8,2	11
Type IV	13	24,1	13	26,5	26
Type V	22	40,7	23	46,9	45

40 years, and 41-50 years.

Classification of the vertical relationship of the maxillary sinus and maxillary first molar according to Kwak et al. namely type I buccal and palatal roots of molar teeth do not come into contact with the sinus floor, type II buccal and palatal roots of molar teeth come into contact with the sinus floor, type III buccal roots of molar teeth penetrate into the sinus cavity above the maxillary sinus floor, type IV palatal roots of molar teeth penetrate into the sinus cavity above the maxillary sinus floor, type V buccal and palatal roots penetrate into the sinus cavity above the maxillary sinus floor. Type I and type II classifications of molar roots do not enter the sinus, while type III, type IV, and type V molar roots enter the sinus. An overview of the age range with non-entry and entry of the first molar root into the maxillary sinus can be seen in Table 2.

Based on Table 2, it can be seen that in the age range of 31-40 years, the highest number of maxillary right first molar roots entered the maxillary sinus. Similarly, in the maxillary left molar in the age range of 31-40 years.

Table 3 shows that the highest number is found in type V classification for vertical relationship of maxillary sinus and maxillary right first molar root, while type I has the lowest number. The percentage in each classification is type I 7.4%; type II 14.8%; type III 13%; type IV 24.1%; type V 40.7%. Similarly, in the maxillary sinus and left first molar root, type V had the highest number, while type I had the lowest number. The percentage in each classification is type I 6.1%; type II 12.2%; type III 8.2%; type IV 26.5%; type V 46.9%.

Figure 1 shows that the classification of the vertical relationship between the maxillary sinus and the roots of the right first molar tooth in the age category 20-30 years, the highest number is type V, namely the buccal and palatal roots penetrate into the sinus cavity above the base of the maxillary sinus, age 31-40 years, the highest number is type V classification as in early adulthood, and age 41-50 years, the highest number is type II, namely the buccal and palatal roots of the molar teeth are in contact with the

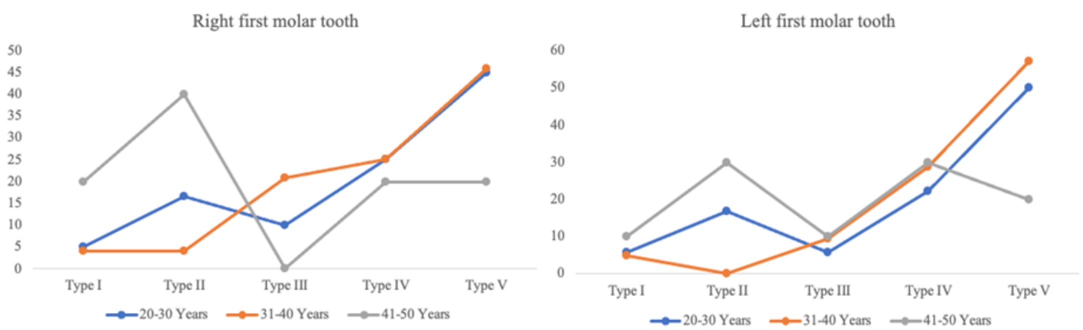

Figure 1. Graphical representation of age by classification of vertical relationship of maxillary sinus and maxillary first molar root

Table 4. Correlation test results between age and vertical relationship classification of maxillary sinus and maxillary first molar root by CBCT

	r	*P value*
Right first molar	*-0,191*	*0,166*
Left first molar	*-0,167*	*0,252*

*Notes: Spearman Correlation Test with: p < 0.05 (significant)

sinus base.

Classification of the vertical relationship between the maxillary sinus and the roots of the left first molar tooth in the age category 20-30 years, the highest number of type V is obtained, namely the buccal and palatal roots penetrate into the sinus cavity above the base of the maxillary sinus, age 31-40 years, the highest number in type V classification as in early adulthood, and age 41-50 years, the highest number in type II, namely the buccal and palatal roots of the molar teeth are in contact with the sinus base and type IV, namely the palatal roots of the molar teeth penetrate into the sinus cavity above the base of the maxillary sinus.

Based on Table 4, it can be seen that in the maxillary right first molar with a right first molar correlation value of -0.191 which means that the strength of the correlation between age and the classification of the vertical relationship between the maxillary sinus and the roots of the maxillary first molar is weak. The correlation value obtained is negative, which means that the relationship between the two variables is not unidirectional or opposite and can be interpreted that the higher the age, the lower the classification of the vertical relationship between the maxillary sinus and the maxillary first molar tooth root (p-value = 0.166). The statistical test results show that there is no correlation between age and the classification of vertical relationship between maxillary sinus and maxillary first molar root.

The maxillary left first molar with a left first molar correlation value of -0.167 which means that the strength of the correlation between age and the classification of the vertical relationship between the maxillary sinus and the maxillary first molar root is weak. The correlation value obtained is negative, which means that the relationship between the two variables is not unidirectional or opposite and can be interpreted that the higher the age, the lower the classification of the vertical relationship between the maxillary sinus and the maxillary first molar tooth root (p-value = 0.252). The statistical test results show that there is no correlation between age and the classification of the vertical relationship of the maxillary sinus and maxillary first molar tooth roots.

DISCUSSION

This study shows that the most common classification of the vertical relationship of the roots of the maxillary right first molar tooth with the maxillary sinus is in the type V classification, namely the buccal and palatal roots penetrate into the sinus cavity above the base of the maxillary sinus as much as 40.7%, and the lowest number is in the type I classification, namely the buccal and palatal roots of the molar teeth are not in contact with the sinus base as much as 7.4% (Figure 1). The results of the number of classifications of the vertical relationship of the roots of the left first molar tooth with the maxillary sinus show the same results as the right first molar tooth with the highest number being type V as much as 46.9% and the lowest number being type I as much as 6.1% (Figure 1).

The results of this study are supported by research conducted by Anna et al. regarding the relationship between the roots of the maxillary teeth and the base of the maxillary sinus conducted in Poland stated that the classification of vertical relationship type V which means that both tooth roots have penetrated the base of the maxillary sinus is the highest number of 43.18%, while type I has the lowest number of about 11.36%. [16] The results of the classifications of the vertical relationship of the roots of the left first molar tooth with the maxillary sinus showed the same results as the right first molar tooth with the highest number of type V at 71.79%, while type I had the lowest number of 5.13%.[16] This occurs because the floor of the maxillary sinus is formed by the alveolaris processus and the maxillary palate, with the lowest part of the maxillary sinus floor generally being between the roots of the first molar and second molar.[17]

The results of this study show differences with research conducted by Carlos et al, which found that the highest number of classification of the relationship between the roots of the maxillary first molar teeth and the maxillary sinus is type II reaching 44.67%, while type V has the lowest number of about 4.67%.[14] The difference in results between this study and the research conducted by Carlos et al, can not only be attributed to differences in research methods, but also to the diversity of ethnic characteristics in the population analyzed.[18] The results of this study show that there is no correlation between age and vertical relationship classification of maxillary sinus and maxillary first molar tooth roots.

The results of this study showed that there was no correlation between age and the classification of vertical relationship between maxillary sinus and maxillary first molar root. This could be due to the unequal population size in all categories. The results of the classification of the vertical relationship of the maxillary sinus and the roots of the right first molar teeth based on age were obtained in the age category 20-30 years the largest number was type V, age 31-40 years the largest number was type V, and age category 41-50 years the largest number was type II. This shows that in this study the increasing age, the lower the vertical relationship classification.

The Tian et al. study used three vertical relationship classifications, namely Type IS root tip extending upward or inside the maxillary sinus floor, Type CO root in contact with the maxillary sinus floor, and Type OS root extending downward or outside the sinus floor. The study showed that with increasing age, the frequency of premolar and molar root IS type decreased in the Chinese population. Type IS was common in the age group of 20 to 40 years and rare in the age group of more than 60 years.[19] This suggests that the average distance of maxillary molar teeth to the sinus floor increases with age.[19]

Maxillary sinus volume development generally ends at the age of 21 to 30 years when the maxillary third molar has erupted.[20] Maxillary sinus volume will decrease after the maxillamal growth period and the sinus floor can move upward, unless there is a disturbance such as tooth extraction that causes sinus pneumatization.[20] Reduced maxillary sinus volume can be caused by mineral loss in the bone matrix of all body structures surrounding the maxillary sinus, causing maxillary sinus contraction.[21] However, this change can occur faster or slower depending on the individual.

Research conducted by Juni Pei et al. showed that the distance between the roots of molar teeth and the base of the maxillary sinus increases with age. This finding suggests that the risk of molar tooth extraction, endodontic therapy, or implant placement is relatively higher in the adolescent age group.[22] In addition, genetic, environmental, habitual, and racial factors can affect the size of the maxillary sinus.[23]

Genetic factors can cause anatomical variations in each human due to differences in human inherited genetics. In addition to genetic factors, anatomical variations can also be influenced by environmental factors.[23] The body's anatomy tends to adapt to the environmental conditions in which the individual lives, so each person living in a different environment may show higher anatomical variations.[23] Individual habits can be a contributing factor to maxillary sinus variation in humans, for example, smoke and harmful substances from smoking can cause irritation to the lining. In addition, alcohol consumption can also cause swelling of the nasal membranes and sinuses.[23] So it is important to evaluate the relationship between the maxillary sinus and the maxillary first molar roots to avoid complications during or after dental treatment.[8]

CONCLUSION

The root of themaxillary first molar tooth entering the maxillary sinus reaches the highest number in the age range of 31-40 years. The vertical relationship between the maxillary sinus and the root of the right first molar tooth, according to Kwak's classification, can be divided into five types starting from the highest number of type V, type IV, type II, type III, type I. Meanwhile, the roots of the left maxillary first molar tooth are type V, type IV, type II, type III, type I. However, there is no significant correlation between age and classification of vertical relationship of maxillary sinus with maxillary first molar root.

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None.

FOOTNOTES

All authors have no potential conflict of interest to declare for this article. This study was conducted in accordance with the declaration of Helsinki and was approved by the Research Ethics Committee of Padjadjaran University Bandung (1282/UN6.KEP/EC/2023) on October 19, 2023. All procedures conducted were in accordance with the ethical standards.

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Unraveling the hidden connection: Impacted third molar classification and mandibular canal proximity on panoramic radiographs

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ABSTRACT

Objectives: This research is aimed to determine the relation between impacted mandibular third molar's classification and mandibular canal proximity with panoramic radiograph at RSKGM-P FKG UPDM (B).

Materials and Methods: This research used an analytical cross-sectional study. The number of samples in this study was 387 lower third molars from 206 digital panoramic radiographs. The samples were then analyzed based on their classification and their relation to the mandibular canal.

Results: The result showed in Pell & Gregory classification, the most related to the mandibular canal is class III (65.8%) with p = 0,000 and position B (58.1%) with p = 0,000. Based on the Winter classification, mesioangular angulation is the most related to the mandibular canal (52.9%) with p = 0,015. Based on the Rood & Shehab classification, it was found that the dominant relation A was 65% in class III with p = 0,000, in position B (58.3%) with p = 0,001, and in mesioangular angulation (61.1%) with p = 0,000.

Conclusion: This study shows that the less space available in the mandible, the deeper the position of the impacted tooth in the jaw and their angle affects the proximity of the impacted tooth to the mandibular canal and the radiographic sign of the proximity of the impacted mandibular third molar root to the mandibular canal. This illustrates the need to perform a panoramic radiographic examination prior to performing any intervention on the mandibular third molar.

Keywords: *Impaction, lower third molar, radiographic image, mandibular canal, panoramic radiograph*
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INTRODUCTION

An impacted tooth is a pathological condition characterized by tooth failure to errupt, fully or partialy into the dental arch within the expected timeframe, resulting in a lack of normal functional positioning.[1,2] Third molars are the most frequently affected by impaction, with an incidence ranging from 9.5% to 68% across different populations.[3,4] This phenomenon can be attributed to the eruption of the third molar occurring as the final stage of tooth development, typically between the ages of 16 and 25. Insufficient space for the tooth to erupt properly is a common consequence of this timing.[3,5]

Contributing factors to the occurrence of impacted lower third molars include, but are not limited to, the smaller size of the alveolar bone arch in comparison to the total length of the dental arch.[1,6] The dental arch is subject to variation between individuals as a consequence of environmental, nutritional, genetic, racial and gender-related influences.[7] Furthermore, changes in dietary patterns towards softer foods have been identified as a potential trigger for impaction. This is due to the fact that such foods do not require the exertion of significant muscular force from the chewing muscles, which can lead to a reduction in jaw growth stimulation and an increased likelihood of dental impaction.[5,6,8]

An impacted tooth can cause food to become trapped around the affected teeth, which can make it more difficult for patients to clean them effectively. This can increase the risk of developing cavities, which can cause pain and potentially affect the distal aspect of the second molar.[1,9,10] Pericoronitis can also occur as a result of repeated trauma to the soft tissue covering the occlusal surface of an impacted mandibular third molar, which is known as the operculum. The accumulation of food beneath the operculum, which is challenging to clean, can also result in the colonization of bacteria and the subsequent development of pericoronitis. Furthermore, impacted teeth can also result in additional complications, including periodontal disease in adjacent teeth, root resorption of nearby teeth,

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odontogenic cysts and tumours, and even fractures in the jaw. [1] The surgical procedure employed to extract impacted lower third molars is known as odontectomy.[11] Complications following odontectomy for lower third molars have been reported with a prevalence ranging from 2.6% to 30.9%. These include bleeding, swelling (edema), pain, trismus, and nerve injury.[12]

To minimise the occurrence of neurological complications during and after surgery, good anatomical knowledge and radiographic examination are required to identify risk factors and determine the appropriate surgical procedure.[13,14] One of the examination methods that can be used to diagnose impacted teeth is panoramic radiograph.[15] Panoramic radiography is commonly used for clinical purposes, including evaluation of trauma such as jaw fractures, third molar positioning, extensive dental or bone disease, known or suspected large lesions, tooth development and eruption (especially in mixed dentition), impacted or unerupted teeth and root remains (in edentulous patients), temporomandibular joint (TMJ) pain, and developmental abnormalities.[16] Panoramic radiograph is an effective method for the preoperative evaluation of mandibular third molars, as it can be used to identify the position of the third molars and their proximity to the mandibular canal.[6]

The mandibular canal is a bilateral bony structure that begins at the mandibular foramen on the medial side of the mandibular ramus, extending downward and forward, and ends at the mental foramen.[17–21] This channel is connected to the roots of the lower jaw teeth through branches along the mandibular canal.[19,20] The depth of the third molar in the mandibular arch, the angulation of the tooth, and the position of the tooth roots in relation to the mandibular canal can influence the risk of neurosensory injury to the inferior alveolar nerve.[6]

At present, the relation between impacted mandibular third molars according to the Pell-Gregory and Winter classifications to the mandibular canal has not been studied much in Indonesia. There are several studies that examined the apical proximity of impacted mandibular third molars according to the Winter and Pell & Gregory classifications to the mandibular canal. However, these studies have not explained the relation between the classification of impacted mandibular third molars and their proximity to the mandibular canal. Therefore, the researcher wanted to investigate the relation between the impacted mandibular third molar's classification and their proximity to the mandibular canal from panoramic radiograph.

MATERIALS AND METHODS

This study used an analytical approach with a cross-sectional study design. The data employed in this study were secondary data, comprising digital panoramic radiographic results pertaining to patients at RSKGM-P UPDM(B). The population under investigation comprised all digital panoramic radiography data pertaining to patients with impacted mandibular third molars within the radiology installation of RSKGM-P UPDM(B) between July 2023 and January 2024. A total of 206 samples were utilized in this study through the application of the total sampling technique. The inclusion criteria for this study were as follows: Panoramic radiographs of RSKGM-P UPDM(B) patients aged between 17 and 45 years, panoramic radiographs of impacted mandibular third molars with perfectly formed roots, panoramic radiographs with good quality and clarity, as well as a clear image of the ramus and angle of the mandibular inferior border. The exclusion criteria for this study included panoramic radiographs with missing mandibular second molars and those of impacted third molar patients with pathological abnormalities in the mandibular root and canal, as well as artifacts on panoramic radiographs. All panoramic radiographs were obtained using the Acteon X-Mind Prime 3D Digital Panoramic X-ray unit and subsequently evaluated with the Ais 2D App software 5.0 version.

The impacted mandibular third molar teeth were classified using the Pell and Gregory system (based on the available space and position) and the Quek et al. system, which was adapted from Winter's system based on the angulation of the teeth, as well as their relation to the mandibular canal and the radiographic appearance that was observed. Subsequently, the images of the roots of the impacted mandibular third molar teeth in relation to the mandibular canal were categorized according to seven radiographic criteria as outlined by Rood & Shehab. For the purposes of statistical analysis, univariate and bivariate analysis with the Chi-square test was employed in order to facilitate comparison of ratios according to age and gender. The statistical analysis was conducted using IBM SPSS Statistics Version 25 software. The level of statistical significance was set at $p < 0.05$.

Pell & Gregory's classification was based on the relation between the mesiodistal diameter of the impacted tooth and the available space between the distal surface of the second molar and the mandibular ramus ascendens. The classification was as follows: class I (when there was sufficient space between the distal surface of the second molar and the mandibular ramus for the mesiodistal width of the third molar to fit), class II (when the space between the distal surface of the second molar and the mandibular ramus was smaller than the mesiodistal width of the third molar), class III (when there was no space between the distal surface of the second molar and the mandibular ramus and the third molar was completely inside the mandibular ramus).[3,6,13,15] The Pell & Gregory classification is based on the relation between the depth and the occlusal plane and cervical line of the second molar tooth, which can be categorised into three positions as follows: Position A is characterised by a third molar that is positioned higher than or at the same level as the occlusal

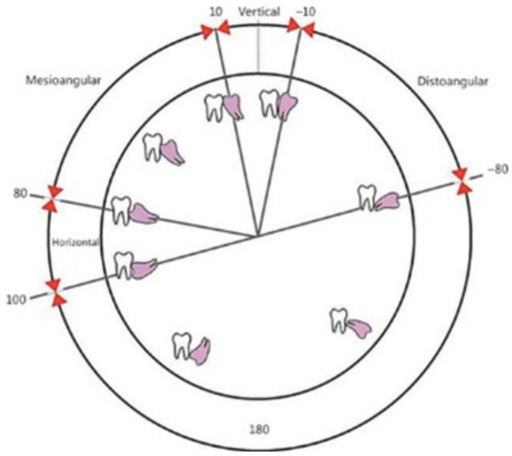

Figure 1. Quek et al.'s classification adapted from Winter's classification[22]

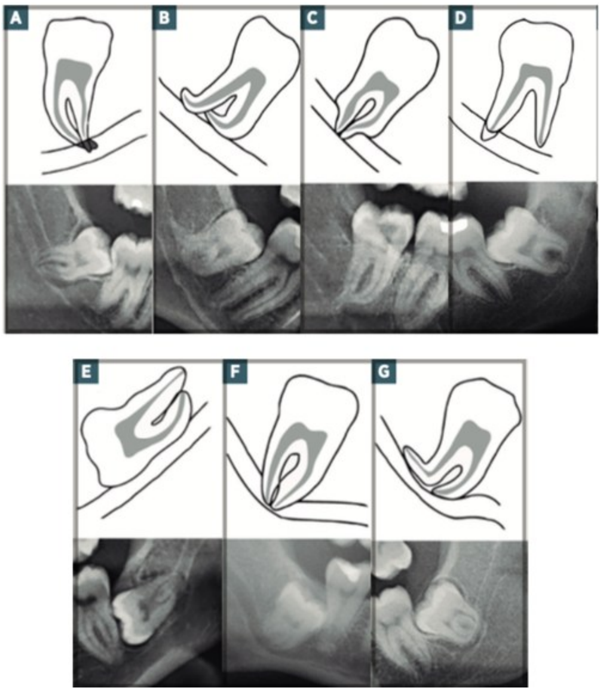

Figure 2. Radiographic signs of the proximity of the roots of impacted mandibular third molars to the mandibular canal by Rood & Shehab. (A) root darkening, (B) root deflection, (C) root narrowing, (D) dark and bifid apex, (E) mandibular canal discontinuity, (F) mandibular canal deflection, and (G) narrowing of the mandibular canal[6]

plane of the second molar. Position B is defined by a third molar that is situated between the occlusal plane and the cervical line of the second molar. Position C is identified by a third molar that is positioned below the cervical line of the second molar. [3,6,13,15] Quek et al.'s classification, which was adapted from Winter's classification, is based on angulation. It includes the following categories: vertical (10° to -10°, whereby the long axis of the third molar is parallel to the long axis of the second molar), mesioangular (11° to 79°, whereby the long axis of the third molar is inclined mesially), distoangular (-11° to -79°, whereby the long axis of the third molar is inclined distally), horizontal (80° to 100°, whereby the long axis of the third molar is perpendicular to the long axis of the second molar), and other (101° to -80°).[3,15,22]

The proximity between the impacted mandibular third molar and the mandibular canal could be described in three ways, namely: close (if the root of the mandibular third molar contacted the superior edge of the mandibular canal), related (if the root of the mandibular third molar passed the superior edge of the mandibular canal and was impacted radiographically), and not close (if there was a distance between the root of the mandibular third molar and the superior edge of the mandibular canal). The study observed seven radiographic signs of the proximity of the roots of impacted mandibular third molars to the mandibular canal, as described by Rood & Shehab. These signs included root darkening, root deflection, root narrowing, dark and bifid apex, mandibular canal discontinuity, mandibular canal deflection, and narrowing of the mandibular canal.[23,24]

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RESULTS

The study sample comprised of 157 female and 49 male participants, representing a gender ratio of 76.2% to 23.6%, respectively. The age group most frequently affected by impaction of the mandibular third molar teeth is 20-25 years old, as evidenced by 159 samples (77.2%). A total of 387 mandibular third molar impaction teeth were obtained from the 206 samples used in this study. The most prevalent classifications identified in this study were Class III, position B, and mesioangular angulation. Of the 387 impacted mandibular third molar teeth, 310 were related to the mandibular canal (80.1%), with the most dominant A-relation being 180 teeth (46.5%).

This study revealed a significant correlation between the classification of mandibular third molar impaction teeth according to Pell & Gregory, based on their class and their proximity to the mandibular canal. Table 2 illustrates that maxillary third molar impaction teeth of class III are more prevalent in relation to the mandibular canal (65.8%).

Table 3 indicates that position B is the dominant position in relation to the mandibular canal (58.1%). Furthermore, the Pell & Gregory classification based on position demonstrates a significant relation with the proximity between the teeth and the mandibular canal.

The results of the analysis presented in Table 4 indicate that the impacted tooth of the mandibular third molar with mesioangular angulation is predominantly associated with the mandibular canal (52.9%), with a p-value of 0.015. This suggests a significant relation between the impacted tooth of the mandibular third molar according to Winter's classification and the radiographic image of proximity to the mandibular canal based on proximity.

Table 5 indicates that class III mandibular third molar impaction teeth exhibited the highest degree of relation A (65%). Furthermore, there was a statistically significant correlation between the classification of mandibular third molar impaction teeth according to Pell & Gregory by class and the Rood & Shehab classification. The results of the data analysis indicated that the relation had a p-value of 0.000.

Table 6 illustrates that the majority of impacted mandibular third molars in position B with relation A were observed, accounting for a significant

Table 1. The distribution of research sample based on age and gender

Age	Gender				Total	
	Male		Female			
	N	%	N	%	N	%
18	0	0%	3	1,5%	3	1,5%
19	1	0,5%	13	6,3%	14	6,8%
20	7	3,4%	19	9,2%	26	12,6%
21	3	1,5%	18	8,7%	21	10,2%
22	5	2,4%	18	8,7%	23	11,2%
23	8	3,9%	20	9,7%	28	13,6%
24	9	4,4%	29	14,1%	38	18,4%
25	4	1,9%	19	9,2%	23	11,2%
26	4	1,9%	1	0,5%	5	2,4%
27	2	1%	5	2,4%	7	3,4%
28	1	0,5%	2	1%	3	1,5%
29	0	0%	2	1%	2	1%
31	1	0,5%	2	1%	3	1,5%
32	0	0%	3	1,5%	3	1,5%
33	0	0%	1	0,5%	1	0,5%
34	1	0,5%	0	0%	1	0,5%
35	1	0,5%	0	0%	1	0,5%
40	2	1%	2	1%	4	1,9%
Total	**49**	**23,8%**	**157**	**76,2%**	**206**	**100%**

Table 2. The relation between the classification of impacted mandibular third molars according to Pell & Gregory and their proximity to the mandibular canal

Variable	Pell & Gregory's classification is based on Class						Total		*p-value*
Proximity	Class I		Class II		Class III				
	N	%	N	%	N	%	N	%	
Close	5	8,8%	25	43,9%	27	47,4%	57	100%	0,000
Related	3	1%	103	33,2%	204	65,8%	310	100%	
Not Close	0	0%	15	75%	5	25%	20	100%	
Total	8	2,1%	143	37%	236	61%	387	100%	

Table 3. The relation between the Pell & Gregory classification of impacted mandibular third molars based on their position and proximity to the mandibular canal

Variable	Pell & Gregory's classification is based on Position						Total		p-value
Proximity	Position A		Position B		Position C				
	N	%	N	%	N	%	N	%	
Close	39	68,4%	18	31,6%	0	0%	57	100%	0,000
Related	127	41%	180	58,1%	3	1%	310	100%	
Not Close	13	65%	6	30%	1	5%	20	100%	
Total	179	46,3%	204	52,7%	4	1%	387	100%	

Table 4. The relation between the classification of impacted mandibular third molars according to Winter based on their angulation and proximity to the mandibular canal

Variable	Winter's classification based on Angulation										Total		p-value
Proximity	Vertical		Mesioangular		Horizontal		Distoangular		Others				
	N	%	N	%	N	%	N	%	N	%	N	%	
Close	21	36,8%	23	40,4%	4	7%	9	15,8%	0	0%	57	100%	0,015
Related	83	26,8%	164	52,9%	23	7,4%	32	10,3%	8	2,6%	310	100%	
Not Close	5	25%	7	35%	1	5%	4	20%	3	15%	20	100%	
Total	109	28,2%	194	50,1%	28	7,2%	45	11,6%	11	2,8%	387	100%	

Table 5. Relation between impacted lower third molars according to Pell & Gregory classification based on class and radiographic proximity to the mandibular canal according to Rood & Shehab classification

Variable	Pell & Gregory's classification is based on Class						Total		p-value
Rood &Shehab's Classification	Class I		Class II		Class III				
	N	%	N	%	N	%	N	%	
Relation A	3	1,7%	60	33,3%	117	65%	180	100%	0,000
Relation B	0	0%	8	36,4%	14	63,6%	22	100%	
Relation C	0	0%	20	51,3%	19	48,7%	39	100%	
Relation D	0	0%	1	11,1%	8	88,9%	9	100%	
Relation E	0	0%	1	4,8%	20	95,2%	21	100%	
Relation F	0	0%	7	24,1%	22	75,9%	29	100%	
Relation G	0	0%	6	60%	4	40%	10	100%	
Others	5	6,5%	40	51,9%	32	41,6%	77	100%	
Total	8	2,1%	143	37%	236	61%	387	100%	

Table 6. Relation between impacted lower third molars according to Pell & Gregory classification based on position and radiographic proximity to the mandibular canal according to Rood & Shehab classification

Variable	Pell & Gregory's classification is based on Position						Total		p-value
Rood &Shehab's Classification	Position A		Position B		Position C				
	N	%	N	%	N	%	N	%	
Relation A	74	41,1%	105	58,3%	1	0,6%	180	100%	0,001
Relation B	9	40,9%	13	59,1%	0	0%	22	100%	
Relation C	21	53,8%	18	46,2%	0	0%	39	100%	
Relation D	4	44,4%	4	44,4%	1	11,1%	9	100%	
Relation E	5	23,8%	15	71,4%	1	4,8%	21	100%	
Relation F	10	34,5%	19	65,5%	0	0%	29	100%	
Relation G	4	40%	6	60%	0	0%	10	100%	
Others	52	67,5%	24	31,2%	1	1,3%	77	100%	
Total	179	46,3%	204	52,7%	4	1%	387	100%	

proportion (58.3%). Furthermore, a notable relation was identified between the Pell & Gregory classification based on position and the Rood & Shehab classification, with a p-value of 0.001.

Table 7 demonstrates that the lower portion of the teeth exhibiting mesioangular angulation is predominantly associated with A (61.1%). The data analysis of the correlation between the Winter classification and the Rood & Shehab classification yielded a p-value of 0.000, indicating a statistically significant relation between the two.

DISCUSSION

The findings of this study indicate that the majority of samples exhibiting impaction on the

Table 7. Relation between impacted lower third molars according to Winter classification based on angulation and radiographic proximity to the mandibular canal according to Rood & Shehab classification

Variable	Winter's classification based on Angulation										Total		p-value
Rood &Shehab's Classification	Vertical		Mesioangular		Horizontal		Distoangular		Others				
	N	%	N	%	N	%	N	%	N	%	N	%	
Relation A	44	24,4%	110	61,1%	8	4,4%	14	7,8%	4	2,2%	180	100%	0,000
Relation B	5	22,7%	9	40,9%	1	4,5%	4	18,2%	3	13,6%	22	100%	
Relation C	16	41%	18	46,2%	0	0%	5	12,8%	0	0%	39	100%	
Relation D	2	22,2%	5	55,6%	1	11,1%	1	11,1%	0	0%	9	100%	
Relation E	3	14,3%	5	23,8%	10	47,6%	2	9,5%	1	4,8%	21	100%	
Relation F	10	34,5%	12	41,4%	1	3,4%	6	20,7%	0	0%	29	100%	
Relation G	3	30%	5	50%	2	20%	0	0%	0	0%	10	100%	
Others	26	33,8%	30	39%	5	6,5%	13	16,9%	3	3,9%	77	100%	
Total	109	28,2%	194	50,1%	28	7,2%	45	11,6%	11	2,8%	387	100%	

mandibular third molar teeth were female, with 157 samples (76.2%) out of 206 samples (Table 1). Similarly, research conducted by Lacerda-Santos et al, reported a similar prevalence of female subjects, with 711 female samples (65.2%) out of a total of 1090 samples.[6] This finding was also conveyed in research conducted by Yasin et al, Akbar et al, and Tenrilili et al.[15,23,25] The aforementioned statement can be attributed to the existence of discrepancies in the duration of the growth period between males and females, particularly during the period of maximum growth.[15,26] The average age at which the growth spurt occurs in females is 12 years, while in males it occurs at 14 years. [26] This growth spurt exerts influence beyond that of impaction, affecting height and weight. [15,27] A study conducted by Adeyemo and colleagues demonstrated a correlation between height and impaction status in mandibular third molar teeth. Subjects who experienced impaction of mandibular third molar teeth exhibited significantly lower height compared to subjects whose mandibular third molar teeth were fully erupted.[27] Similarly, in the growth In terms of growth patterns, women typically exhibit a shorter skeletal growth pattern and a relatively faster growth rate compared to men.[15] This results in the cessation of jaw growth in women coinciding with the eruption of the third molar tooth. This assertion is supported by research conducted by Azhari et al., which suggests that in women, jaw growth remains relatively constant from the age of 16 years, while in men, it reaches its peak at the age of 17 years.[28] However, the rate of jaw growth is inversely proportional to the eruption of the third molar tooth. Women experience a slowdown in jaw growth earlier than men, while in men the lower jaw third molar tooth erupts about three to six months earlier than women[15,28]

Furthermore, in Table 1 we can see that the most prevalent age range identified in this study was between 20 and 25 years. Similarly, Tenrilili et al. and Muhamad et al. reported comparable findings, indicating that the age range of 21 to 30 years was the most prevalent in their research samples. [15,29] These results may be influenced by the eruption time, which is typically around 17 to 21 years of age [25] Some sources suggest that third molars typically erupt between the ages of 16 and 25.[5] Conversely, Muhamad et al. and Akbar et al. observed a low prevalence of tooth impaction in older age groups, which they attributed to the possibility that previous tooth extractions may have been performed in individuals of advanced age.[25,29]

The results of the study indicated that the majority of maxillary third molar impaction teeth were observed in class III, representing 236 teeth (61%) out of 387 teeth (Table 2). This result is not aligned with the findings of Haddad et al. and Akbar et al., who reported that the impaction of mandibular third molar teeth in class II was the most prevalent.[25,30] As previously discussed, this classification describes whether there is sufficient space for the mandibular third molar teeth to erupt. In class III, it can be interpreted that there is insufficient space for the mandibular third molar teeth to erupt, resulting in the majority of teeth residing within the mandibular ramus.[13,15,31] This can be attributed to one of the etiologies of impaction, namely the alveolar bone arch being smaller than the total length of the dental arch.[1] The lack of jaw arch is influenced by several factors, one of which is gender.[7] As previously noted, the majority of samples in this study were female. Some studies have indicated that the growth of the jaw in women ceases when the third molar tooth erupts.[15,23] The maturation of the female jawbone can also be influenced by the menstrual cycle and physical activity, resulting in accelerated and more robust bone growth.[9] Dietary factors also play a role in bone growth, with a diet rich in fibre increasing muscle activity and promoting jaw growth.[15]

The data analysis in Table 3 revealed that position B is the most prevalent impacted tooth position of mandibular third molars in this study, affecting 204 teeth (52.7%) out of 387 teeth. This finding is in accordance with the results of previous research conducted by Primo et al. and Haddad et al., which indicates that position B is the most dominant position in comparison to positions A and C. [30,32] Additionally, a previous study has suggested that the occurrence of impaction on mandibular third molar teeth may be influenced by factors such as mandibular ramus height and mandibular ramus angle. In the case of mandibular third molar impaction teeth, position A was found to exhibit the highest ramus and the lowest ramus height in position C. [33] Based on the size of the mandibular ramus angle, no significant difference was observed between the impacted teeth of the mandibular third molar in positions A and C. However, in position B, a smaller ramus angle was noted.[33] It can therefore be concluded that the probability of impaction is higher in cases where the mandibular ramus is of a shorter height and the angle of the mandibular ramus is smaller. [25,33] This is supported by the findings of a study which demonstrated that the ramus in males is of a greater height than in females.[34]

In this study, the classification of maxillary third molar impaction teeth according to Winter revealed that the most frequently observed angulation was mesioangular, which was identified in 194 teeth (50.1%) of 387 teeth (Table 4). These findings align with those of Passi et al., who reported a significantly higher prevalence of mesioangular angulation compared to other angulations, with 123 teeth (49.2%) exhibiting this feature out of 250 teeth.[4] Additionally, the findings of Dusak et al. further support the assertion that mesioangular angulation is more prevalent. Of the 342 teeth examined, 67.54% exhibited mesioangular angulation.[5] The results of these studies may be attributed to the fact that the average growth and eruption direction of the mandibular third molar teeth is antero-superior, and the numerous findings of the location of the third molar tooth seed, which is tilted mesially based on the lateral aspect.[8,35]

Based on Table 2, 3 and 4, the most prevalent teeth observed in this study were teeth related to the mandibular canal, comprising 310 teeth (80.1%) out of the 387 total teeth analysed. The results of this study are in accordance with the findings of Haddad et al., who examined 1,060 impacted mandibular third molar teeth and observed that 872 (54.5%) were associated with the mandibular canal.[30] . However, these results are not aligned with the conclusions of Yasin et al. In their study, it was stated that among 1,090 impacted teeth of the mandibular third molar, there were 723 teeth located far from the mandibular canal (66.33%). [23] This discrepancy could be attributed to the fact that the majority of the teeth in this study were classified as class III according to the Pell & Gregory classification, which is based on the availability of space (Table 1). In contrast, the most impacted teeth of the mandibular third molar in the study conducted by Yasin et al. were found to be in class I.[23] This assertion is supported by the findings of the Yasin et al. study, which indicate that the proximity between mandibular third molar teeth in class III and the mandibular canal is six times higher than in class I.[23] Furthermore, other studies have suggested that women have a high prevalence of tooth root entry into the mandibular canal, with a reported rate of 62.1%.[36] Additionally, the results of this study may be attributed to one of the inclusion criteria employed, namely the formation of complete mandibular third molar tooth roots. In their study, Kamadjaja et al. asserted that fully formed roots tend to make contact with the mandibular canal.[24]

The findings of this study indicate that relation A is the most prevalent in this study, with a total of 180 teeth (46.5%) from a total of 387 teeth (Tabel 5,6 and 7). This result is in accordance with the findings of Lacerda-Santos et al, who reported that 767 teeth exhibited the A relation (45.7%) out of 1677 teeth. [6] Similarly, Kamadjaja and colleagues observed that the A relation was the most prevalent in comparison to other relations.[24] several studies have attributed the darkening image at the root of the impacted mandibular third molar (Relation A) to the loss of tooth substance [37] Following an evaluation using CBCT, it was determined that the image was not caused by a loss of tooth substance, but rather by a thinning of the buccal and/or lingual cortical plates.[37] This can be attributed to a study that indicated a significant correlation between age and lingual cortical plate thickness. Specifically, the lingual cortical plate was observed to be markedly thinner in the apical one-third and middle one-third of the roots of mandibular third molar teeth in individuals aged 21-30 years.[38]

The findings of the relation analysis between the classification of mandibular third molar impaction teeth in accordance with the Pell & Gregory system (based on the availability of space in the dental arch) and the position of the mandibular canal with respect to the midline demonstrate a statistically significant relation ($p = 0.000$) (Table 2). The results indicate a positive correlation between the proximity of the mandibular third molar impaction to the mandibular ramus and the proximity to the mandibular canal. As can be seen in Table 2, the data substantiates this assertion. The results reveal a notable rise in the number of teeth situated in close proximity to the mandibular canal, as well as a significant proportion of teeth related to the canal. In particular, teeth in this vicinity can be categorised as follows: 5 teeth belonging to the mandibular third molars of Class I (8.8%), 25 teeth belonging to Class II (43.9%) and 27 teeth belonging to Class III (47.4%). Additionally, among the teeth related to the mandibular canal, there are three class I teeth (1%), 103 class II teeth (33.2%), and 204 class III teeth (65.8%). These findings are corroborated by the research of Haddad et al., which indicates that impacted mandibular third molar class III teeth are more likely to be in proximity to the mandibular canal than classes I and II.[30] The presence of mandibular third molar teeth that are largely or entirely within the mandibular ramus can be attributed to the lack of space between the distal surface of the second molar tooth and the anterior edge of the mandibular ramus.[6,13] One study has indicated that there is a high probability of mandibular third molars being situated on the lingual side of the mandible. This can be attributed to the findings of other studies which have suggested that the position of the mandibular canal crosses lingually on the roots of mandibular second and third molars, which were previously located on the buccal side of the roots of first molars and premolars.[19,39,40] Researchers suspect that the lack of space may result in potential contact between the mandibular canal and the roots of the mandibular third molars, both on the lingual side of the mandibular canal and between the roots of other teeth.

The results of the analysis of the relation between the classification of impacted teeth of the mandibular third molar according to Pell & Gregory based on position (depth) and the mandibular canal according to proximity demonstrate a significant correlation (p=0.000) (Table 3). It can therefore be concluded that the deeper the position of the impacted tooth of the mandibular third molar, the greater the likelihood of contact or relation to the mandibular canal. This finding is further supported by the research conducted by Khojastepour et al., which states that the deeper the position of the impaction tooth of the mandibular third molar, the position of the tooth is dominantly towards the lingual side of the mandible[39] This statement remains related to the position of the mandibular canal, which is inclined to be located on the lingual side of the mandible at the root of the third molar.[19] Both statements reinforce the researcher's assertion that an increase in depth of the impacted third molar tooth may elevate the probability of contact with the mandibular canal

As evidenced in Table 4, there was a statistically significant correlation between the classification of mandibular third molar impaction teeth by angulation and the proximity of the mandibular canals (p=0.015). These findings demonstrate the high prevalence of mesioangular and vertical angulations in contact with the mandibular canal, either merely touching the outer edge of the canal (i.e., in close proximity) or in direct contact with it. These findings align with those of previous research conducted by Lacerda-Santos et al. dan Haddad et al., ., which demonstrated that both angulations have a higher frequency of contact with the mandibular canal compared to other angulations.[6,30] A study has demonstrated a correlation between the angulation of mandibular third molar teeth and their depth. Afridi et al. have asserted that as the angulation of the teeth increases, the depth of the teeth also increases, as does the proximity to the mandibular canal. [41] As stated by Haddad et al., an increase in the depth of an impacted mandibular third molar tooth accompanied by a change in angle from vertical to either mesioangular or horizontal will result in an elevated risk of interference between the roots of the mandibular third molar and the mandibular canal.[30]

Table 5 illustrates a notable correlation between the classification of impacted mandibular third molars according to Pell & Gregory's classification system, based on based on the availability of space in the dental arch and its relation with the mandibular canal according to Rood & Shehab (P=0.000). The results of the analysis on the relation between the classification of mandibular third molar impaction teeth according to Pell & Gregory based on position (depth) and its relation with the mandibular canal according to Rood & Shehab (Table 6) also demonstrated a significant relation (P=0.001). This is consistent with the findings of Lacerda-Santos et al. who observed that the deeper the impacted third molar is situated within the ramus, the more prevalent the associated signs become.[6] These results can also be attributed to previous findings indicating a tendency for the impacted mandibular third molar to be on the lingual side of the mandible. This positioning allows for contact with the lingual-side mandibular canal when crossing the roots of the mandibular third molar. [19,39,40] This statement can be related to the cause of relation A (darkening of the mandibular third molar root), which is the most dominant relation found in this study. This is due to the thinning of the buccal and/ or lingual cortical plate [37] This is clarified by research which states that the mandibular bone around teeth located on the lingual side of the mandible tends to be thinned or even perforated more than teeth located on the buccal side of the mandible [39] It can be concluded from the aforementioned statements that the lack of space and the deep position of impacted mandibular third molars can increase the frequency of radiographic signs of proximity to the mandibular canal.

Table 7 illustrates the significant relation between the classification of impacted teeth of mandibular third molars according to Winter and their relation with the mandibular canal according to Rood & Shehab (P = 0.000). The study conducted by Lacerda-Santos et al, also indicated a significant correlation between the two variables (P=0.02).[6] This implies that the angulation of the impacted mandibular third molar tooth may influence the perceived proximity to the mandibular canal. The researcher hypothesises that the angulation of the mandibular third molar impaction tooth continues to exert an influence on its depth. This is thought to be related to the presence of the mandibular third molar impaction tooth, which is known to be more prevalent on the lingual side of the mandible.

The results of the precent study indicate that the most prevalent classification system for mandibular third molar impaction is that proposed by Pell and Gregory. This system is based on the classification of teeth according to class and position, with class indicating the available space within the jawbone and position indicating depth. This finding aligns with the additional assertion by Afridi and colleagues that the correlation between Winter's classification of teeth based on angulation and their proximity to the mandibular canal is significant but less pronounced.[41]

CONCLUSION

The results of this study indicate a significant correlation between the Pell & Gregory classification (class and position) and proximity to the mandibular canal. A significant relation was found between the Winter classification and its proximity to the mandibular canal. A significant relation was found between the Pell & Gregory classification (class and position) and the Rood & Shehab classification. The less space available in the mandible, the deeper the position of the impacted tooth in the jaw and its angulation affects the proximity of the impacted tooth to the mandibular canal and radiographic signs of the proximity of the roots of impacted mandibular third molars to the mandibular canal. This highlights the need for a panoramic radiograph prior to any intervention on the mandibular third molar. The results of this study can be used to guide surgical planning and avoid complications due to inferior alveolar nerve injury. Further research could be conducted using the same number of samples based on each classification, as well as based on gender and age. This would enable a comparison of the results and greater accuracy in determining the relation between the classification of impacted mandibular third molar teeth and the radiographic image of their proximity to the mandibular canal.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article. This research has received ethical approval from the Research Ethics Commission of the Faculty of Dentistry, Prof. Dr. Moestopo (Beragama) University with number 141/KEPK/FKGUPDMB/VII/2024. All procedures conducted were in accordance with the ethical standards.

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Approximation length of the mandibular first molar tooth of Bataknese based on gender analyzed using parallel techniques

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ABSTRACT

Objectives: The purpose of this study is to use the parallel technique to approximate the tooth, root, and furcation length of the mandibular first molar in the Bataknese population while accounting for gender differences.

Materials and Methods: The research employs an analytic observational design with a cross-sectional approach. It utilizes secondary data from 90 parallel technique radiographs of patients aged 19-25 years who meet the specific inclusion and exclusion criteria. The radiographs are analyzed to assess tooth length, roots, and furcation of the mandibular first molar. Measurements are conducted using Cliniview software, and the results are processed and analyzed utilizing an independent t-test.

Results: The result showed that the average tooth length in males was 21.60 mm, with the mesial root measuring 13.64 mm, the distal root measuring 12.78 mm, and the furcation measuring 4.25 mm. In females, the average tooth length was 19.50 mm, with the mesial root measuring 12.13 mm, the distal root measuring 11.24 mm, and the furcation measuring 3.56 mm. Males have a greater average length than females.

Conclusion: Male teeth, roots, and furcations are longer than female teeth, according to the study's findings, which were derived via an analysis using the parallel technique. There was a discernible gender difference.

Keywords: *Bataknese, gender, length, mandibular first molar, parallel technique*
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INTRODUCTION

One of the aspects of dentistry that has evolved is radiographic examination. At the moment, it serves as the primary diagnostic method for figuring out how bad oral illness is. Both intraoral (such as periapical bisecting, bitewing, and parallel radiography) and extraoral (such as cephalometry and panoramic radiography) radiographic procedures are used as evaluation techniques. Dental radiography is widely utilized because it generates images that may be used more quickly and accurately to identify abnormalities. This aids in assessing the oral cavity's general health and avoiding unnecessary operations.[1]

In dentistry, periapical radiography is a commonly utilized intraoral projection technique, particularly for endodontic treatment.[2] Periapical radiography is used to display the anatomy of each tooth, from the root to the crown, as well as the surrounding supporting tissues. The quality of the radiograph must be determined before any analysis or interpretation can begin, as low quality will limit the amount of important information that can be extracted from the diagnostic imaging, such as whether the radiograph shows distortion or elongation.[3] In periapical radiography, there are two primary methods: the parallel technique and the bisecting technique. These are a few of the most widely chosen methods for starting case management.[4] The parallel technique can yield more accurate radiographs than the bisecting technique because it minimizes geometric distortion in the orientation of the film, tooth, and central ray.[5] In dental care, the bisecting technique is more frequently used due to better patient adaptability, even if the parallel technique can produce more accurate radiographs.[6] Tooth size diversity across individuals is influenced by a multitude of factors, including hormonal differences between males and females, gender, environment, racial variations, and genetic or hereditary characteristics.[7] Root canal therapy is one of the procedures that ordinary dentists and dental conservation specialists typically perform, depending on its level of difficulty.[8] The gender of an individual affects the size of their teeth. Many teeth in the mouths of males and females are different in size. A person's tooth size is influenced by their race. The morphological traits unique to

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each race influence the variation in tooth size within that race.[9]

The three main races in the globe are Caucasoid, Negroid, and Mongoloid. Mongoloids make up the main race in Indonesia and are divided into two groups: Proto-Malay (Old Malay) which contains the Batak, Toraja, and Dayak tribes, and Deutero-Malay (Young Malay) which includes the Javanese, Banjar, and Balinese tribes.[10] Indonesia is home to a wide variety of ethnic groups and civilizations. One of the ethnic groups of Indonesia is the Bataknese, who live in North Sumatra. According to the 2010 Badan Pusat Statistik census, one of the largest ethnic groups in Indonesia is the Bataknese. This name refers to a group of ethnic groups that reside on and originate from the west and east beaches of North Sumatra Province. There is a sizable Bataknese population in North Sumatra.[11] The mandibular first molar is the most caries-prone tooth in humans, and even in young patients, it usually requires a root canal. Therefore, it is crucial to comprehend the length and curve of the root during root canal therapy to prevent any harm.[12] The average length of the mandibular first molar teeth, root, and furcation in the Bataknese population varies with gender, however, this information is currently unclear. The data that is currently accessible includes a study by Soraya et al. that indicates the average length of the maxillary permanent central incisor in Acehnese students, which is 25.86 mm.[13] The average length of the mandibular first molar in the Bangladeshi population was found to be 20.28 mm in the study by Alam et al.[14] According to Gu et al.'s research, the average length of the Chinese population's first mandibular molar root with two roots, measured vertically from the tip of the root to the CEJ boundary, is 13.16 ± 1.24 mm.[15]

It is quite possible that during root canal therapy, inadvertent incidents, often referred to as procedural blunders, will occur. One of the primary causes of these accidents is natural iatrogenic factors, such as extensive instrumentation in the pulp area. Over-instrumentation during the biomechanical preparation of endodontic therapy, especially in the danger zone of the root-dentin, leads to iatrogenic involvement of the furcation. Alghamdi et al. examined changes in furcation measurements of mandibular and maxillary molar teeth before and after root canal therapy. They found that the average furcation area of the teeth varied significantly between the pre-and post-root canal periods. Measurements of the furcation area taken both before and after root canal therapy demonstrate that endodontic treatments result in over-instrumentation.[16] The main objective of this study is to measure the tooth, root, and furcation length of the mandibular first molar in the Bataknese population using the parallel technique, considering gender variances.

MATERIALS AND METHODS

This study was an observational analytic study using a cross-sectional design. This research has received approval from the ethical commission of the Faculty of Medicine, Universitas Sumatera Utara with reference number 252/KEPK/ USU//2024.

Ninety parallel technique radiographs of patients who met the inclusion and exclusion criteria, aged 19 to 25, from the Dental and Oral Hospital (RSGM) of Universitas Sumatera Utara were used as a secondary sample for this study. The samples needed to be in good visual condition, with the anatomy of the mandibular first molar teeth visible from the apex of the tooth to the tip of the highest cups, CEJ; they also needed to be free of caries at the CEJ, tilted teeth, lacerated roots, and fixed orthodontics. Cliniview 10.1.2 software was then used to measure the length of the tooth, root, and furcation from the gathered radiographs.

The tooth's length was measured along a vertical straight line from the highest cusp tip to the tip of the root (PG). The length of the root was measured along a vertical straight line from the CEJ to the tip of the mesial root (AM) and the distal root (AD). The length of the furcation was

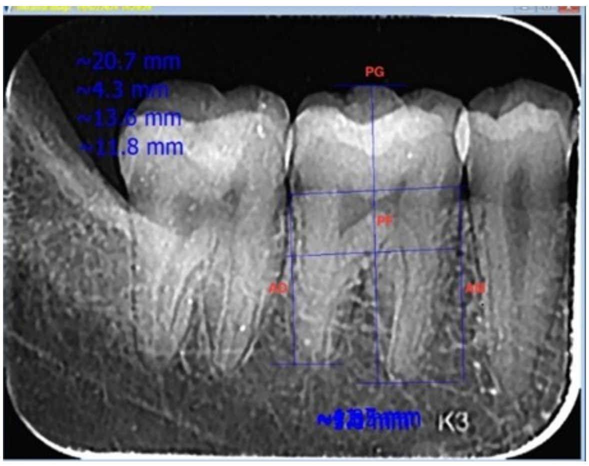

Figure 1. Measurement of the mandibular first molars' tooth length (PG), mesial root length (AM), distal root length (AD), and furcation length (PF)

measured along a vertical straight line from the CEJ to the lowest furcation surface (PF), as shown in Figure 1. Normality tests were conducted on the measurement results using the Shapiro-Wilk test, and if the data were normally distributed, the analysis proceeded with independent t-tests.

RESULTS

According to the study's findings, in the mandibular first molar, males have greater average tooth, root, and furcation lengths than females. It is also observed that the average length value of the mesial roots is greater than that of the distal roots in both males and females. The average value variations are displayed in Table 1 and Figure 2. The results of the data testing are shown in Table 2, where they are regularly distributed and homogeneous ($p > 0.05$). Table 3 demonstrates that, according to parametric testing using independent t-tests, there are significant differences between males and girls in the length of the tooth, root, and furcation of the mandibular first molar ($p < 0.05$).

Table 1. Based on gender, the mandibular first molar's tooth, root, and furcation lengths' mean and standard deviation

Gender		Tooth length	Mesial root length	Distal root length	Furcation length
Male	Mean	21.60	13.64	12.78	4.25
	N	45	45	45	45
	Std. Deviation	.826	.811	.940	.455
Female	Mean	19.50	12.13	11.24	3.56
	N	45	45	45	45
	Std. Deviation	1.333	1.172	1.182	.567
Total	Mean	20.55	12.89	12.01	3.91
	N	90	90	90	90
	Std. Deviation	1.527	1.258	1.316	.618

Table 2. Results of Shapiro Wilk normality and Leven's homogeneity test

Variable	Gender	Shapiro Wilk	Homogen Levene's
Tooth length	Male	.073	-
	Female	.067	-
	Based on mean	-	.060
Mesial root length	Male	.054	-
	Female	.051	-
	Based on mean	-	.064
Distal root length	Male	.123	-
	Female	.075	-
	Based on mean	-	.098
Furcation length	Male	.083	-
	Female	.052	-
	Based on mean	-	.065

Table 3. Result of Independent T-Test

Variable	Independent T-Test (2-tailed)
Tooth length	.000
Mesial root length	.000
Distal root length	.000
Furcation length	.000

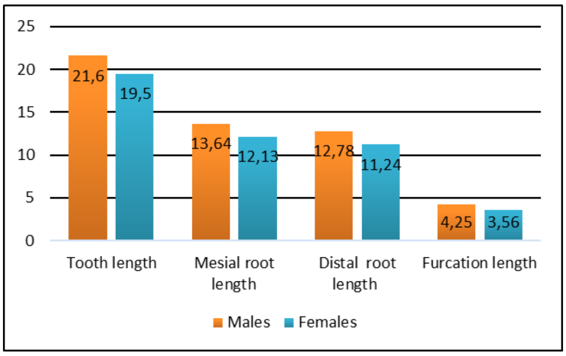

Figure 2. Diagram of the difference in mean values of the tooth, root and furcation length between males and females

DISCUSSION

When a clinician knows an estimated measure of the tooth length, it can be useful to determine the tooth length during therapy. This study used a parallel technique was used to acquire X-rays using a film holder and the periapical photo-alignment method. This method was selected because of its low distortion. This happens as a result of the film's alignment with the tooth's long axis. The length and width of the teeth can be captured in anatomically correct photographs by precisely focusing, immobilizing, and directing the beam with the use of a film holder. This method is simple to apply, comprehend, and understand. When a film holder with a beam centering mechanism is employed, the operator no longer needs to measure angles in both the horizontal and vertical axes, and dimensional corrections can be avoided.[13]

This study's average tooth length is different from that of previous research. Ethnicity or the use of various measuring tools, such as radiography and electronic measurements utilizing apex locators or other methods, maybe the cause of the variations. Using the paralleling technique, the average length of mandibular first molar teeth among all male and female samples was found to be 20.55 mm ± 1.527. Compared to the Madjapa (2018) study, which produced a value of 21.7 mm in the Tanzanian population, this finding is smaller.[17]

Out of all the male and female samples in this study, the mean mesial root length was 12.89 mm ± 1.258 and the mean distal root length was 12.01 mm ± 1.316. This result differs from that of the study by Akhlaghi et al. (2017), which used paralleling radiography to show that a selected group in Iran had an average mesial root length of 15.68 mm and a distal root length of 15.1 mm. This may be because the Aryan race, an Indo-European race, is represented in Iran. The Aryan race is more physically similar to Europeans, having a lighter complexion, higher cheekbones, and eyes that are blue, green, and light brown. In comparison to the Mongoloid race, it has similarities with the Caucasoid race, whose teeth are longer.[18] The average root length among African descendants was 9.94 mm ± 0.85, according to research by Theye et al. (2018) using micro-CT, which is less than the results of this study. There could be racial influences on this. A Negroid race of African heritage, they are characterized by physical attributes like a large or round face, dark skin, curly black hair, and a stocky, tall build. The Negroid race has tiny, rectangular mandibular first molar teeth.[19]

The average furcation length for both male and female samples in this investigation was 3.91 ± 0.618. Using CBCT, Al-Zoubi et al. (2018)'s study discovered that the Saudi population's mandibular first molar teeth had an average furcation length of 4.17mm ± 1.32. This discrepancy could result from the usage of various radiograph types in addition to racial differences. The Caucasoid race known as Arabs have longer teeth than the Mongoloid race. In this work, measurements were made using Cliniview software and periapical radiographs utilizing the paralleling approach. Prior research has employed CBCT and NewTom 3G software for measurements (NNT, QR SRL); Scanora 3D for OnDemand, Cypermed Inc., Irvine, CA), which offers 3D measurements that are more precise and detailed. The size discrepancy could potentially be attributed to variations in radiography type selection.[20] This study used periapical intraoral radiographs, and the radiograph results only provided a two-dimensional image. Previous studies using micro-CT (Computed Tomography) and CBCT (Cone Beam Computed Tomography) can offer three-dimensional reconstruction. In contrast, a prior study by Preminio et al. used Micro-Tomography, which can display both sides of the buccal and lingual sections, to measure the length of the buccal mandibular first molar furcation to 2.49 mm and 3.18 mm on the lingual part. The average furcation, which can only be measured on the buccal part in this study, is 3.91 mm shorter on the buccal part, according to the results.[21]

Male and female teeth have different sizes. This is a form of sexual dimorphism caused by higher gene regulation in males. The difference in the development of the first molar teeth between males and females can be explained through biological and hormonal factors. The teeth of males undergo a longer amelogenesis process than those of females. As a result, male teeth are generally larger than female teeth. This is related to differences in the phases of growth and bone maturation influenced by hormones such as estrogen and testosterone.[22] Testosterone levels in men are also higher compared to women during the growth process. During the growth process, men experience up to three times the amount of testosterone compared to women. The permanent teeth begin to appear and the primary teeth are ready to go through each stage of tooth formation, at which time the permanent teeth also begin to develop. When the primary teeth are ready to go through each stage of tooth development, the permanent teeth begin to appear and grow. Testosterone levels peak around the 14th week of pregnancy. This increase indicates that growth is influenced by hormonal factors.[23] Dentin thickness is also influenced by the X and Y chromosomes in both sexes, as the Y chromosome affects both dentin and enamel formation, while the X chromosome is involved only in enamel production. Males tend to have thicker dentin compared to females, so males with XY chromosomes generally have larger teeth than females with XX chromosomes. The developmental differences of other teeth, such as incisors, canines and premolars also follow a similar pattern to the molars, but with certain variations.[24]

Tooth growth is also influenced by environmental factors and nutrition. A person's healthy growth and development depends on the nutrients they consume, which can lead to variations in tooth size both during pregnancy and after giving birth. Calcium and protein are two nutrients that are very crucial for the growth of bones and teeth. A mother who consumes little calcium during her pregnancy will affect her unborn child's teeth. Another nutrient that is necessary for the growth and development of teeth is vitamin A. A shortage in vitamin A can cause the mineralization process to slow down, changing the chemical composition of dentin. The size of each person's teeth will vary based on the nutrition they take in throughout pregnancy. An environment's influence on a race's dental morphological characteristics can also be linked to a location's geographic factors.[9]

The results of this study demonstrate that, in the Bataknese utilizing the parallel technique, the mean values of mandibular first molar length, mesial root length, distal root length, and furcation length are higher in males than in females. Despite having the same dental anatomy, men's and women's teeth are not the same size because of several factors that substantially affect tooth size.[25] The theory of Fidya et al. (2016) states that variations in male and female size, height, and appearance are referred to as sex differences. Teeth have a relatively low observer error rate and can yield trustworthy information. However, because of their small size, teeth also require very accurate measurements.[26] Dimorphism is a trait shared by humans and other living creatures that is defined by variations in the size of various body tissues brought on by sex differences. Males and females differ in size, shape, color, and other dimensions as a result of these dimensional alterations.[27]

When completing root canal therapy in a location without radiography, these results may help estimate the working length by showing the length and furcation of the teeth and roots in the Bataknese. This study emphasizes how crucial it is to take ethnic and gender variations in dental morphology into account. Male and female Batak people differ significantly in their tooth, root, and furcation lengths, which emphasizes the need for a customized approach in dental practice and forensic applications. By identifying and taking these variations into account, dental professionals can enhance treatment outcomes and boost the precision of forensic identification.

CONCLUSION

Male teeth, roots, and furcations are longer than female teeth, according to the study's findings, which were derived via an analysis using the parallel technique. There was a discernible gender difference.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article. This research has received approval from the ethical commission of the Faculty of Medicine, Universitas Sumatera Utara with reference number 252/KEPK/USU//2024. All procedures conducted were in accordance with the ethical standards.

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Description of the shape and position of the condyles in Kennedy classification class I, II, III, and IV patients through panoramic radiography

(At RSUD Ulin and RSGM Gusti Hasan Aman Banjarmasin from January 2018—January 2024)

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ABSTRACT

Objectives: Tooth loss occurs when the tooth detaches from the socket. Cases of partial tooth loss can cause differences in the shape and position of the condyles. This study aimed to know the description of the frequency distribution of normal and abnormal condyle shapes and positions in Kennedy classification case patients class I, II, III, IV.

Materials and Methods: This research used a cross-sectional descriptive approach. The sample used secondary data from 120 digital panoramic radiographic photos of patients aged 30-70 from January 2018 to January 2024 at Ulin Hospital and Gusti Hasan Aman Hospital Banjarmasin.

Results: Based on the research results at RSUD Ulin and RSGM Gusti Hasan Aman Banjarmasin, the round shape was the most common condyle shape found in patients with Kennedy classification, with most condyle positions pointing to the anterior. The change in the shape and position of the condyle becomes pathological due to the long-term loss of part of the tooth.

Conclusion: The frequency distribution of the shape and position of the condyle of patients with Kennedy classification class I, II, III, IV was the round shape as the most common condyle shape experienced by patients which is one of the normal condyles shapes, and an abnormal position of TMJ condition pointing anteriorly.

Keywords: *Edentulous, tooth loss, condyle, shape, position, temporomandibular joint*

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INTRODUCTION

Tooth loss is a condition where a tooth is detached from its socket. Tooth loss is one of the dental and oral health problems that is often found in society. This can interfere with speech, chewing, aesthetics, and social relationships. Based on WHO data in 2023, the estimated global prevalence of tooth loss is almost 7% among people aged 20 years or older, while those aged 60 years or older have a more than 23% prevalence. The results of the Basic Health Research (RISKESDAS) in 2018 stated that the prevalence of tooth loss in Indonesia was 19% of the total population. Partial tooth loss in South Kalimantan was 17.8%, while in Banjarmasin, 14.10% of the total population.[1–4]

Tooth loss is divided into two types, namely partial tooth loss and complete tooth loss. Partial tooth loss has another name, partial edentulous, a condition where one or more teeth are lost but not completely lost in the part of the dental arch called the edentulous space and is classified by Kennedy's classification class I, II, III, and IV. Complete tooth loss is when both jaw arches no longer have teeth. This tooth loss can interfere with the balance of the arrangement of the teeth and the jaw arch, which disrupts functional activities. The loss of one or more teeth can cause differences in the shape and position of the condyle.[5–8]

The shape of the condyle in the TMJ has two types of shapes: normal and pathological. The condyle's normal shape has five types: round, crooked finger, pointed, angled, and flat. Condyles with pathological shapes are divided into flattening, sclerosis, osteophyte, and erosion. The pathological shape of this condyle is because the mandibular condyle gets a huge load when the mandible functions. This causes adaptive and generative changes. The occurrence of this shape change causes a clicking sound in the TMJ. The correct condyle position is in the mandible's central fossa and shows centric occlusion, affecting the TMJ's physiological function. Condylar dislocation is distinguished based on the location of the condyle relative to the articular fossa of the temporal bone, namely anterior, posterior, superior, and lateral dislocations, each of which can be caused by trauma.[6,9,10]

Temporomandibular conditions can be seen using two-dimensional radiography techniques: panoramic, transcranial, trans pharyngeal (intracranial), and tomography. Among these radiography techniques, panoramic radiography is a two-dimensional technique widely used in dental practice to examine TMJ disorders. The shape and position of the abnormal or changed condyle can be seen using panoramic radiography. All parts of the tooth structure, including the supporting tissues of the jaw, including the condyle, can be seen from the results of the panoramic radiography examination images. Changes in the shape and position of the condyle caused by tooth loss can cause occlusion misalignment. Occlusion misalignment can cause excessive pressure on the temporomandibular joint, which triggers a shift in the position of the condyle to a pathological or abnormal state. Loss of some teeth often causes changes in occlusion which cause changes in occlusion which trigger temporomandibular disorder (TMD).[5,7–9]

Temporomandibular joint disorders (TMD) are disorders that occur in the neuromuscular and musculoskeletal caused by a misalignment between the components of the stomatognathic system, teeth, and surrounding tissues that cause various disorders such as pain in the TMJ and the complex tissues around it, namely muscles, blood vessels, nerves, ligaments, tendons, fibrocartilage, and synovial fluid. Another characteristic of temporomandibular dysfunction is pain in the face, which is called myofascial. This occurs due to occlusal misalignment when chewing food.[5,10,11]

Temporomandibular joint disorders are orofacial disorders that humans often suffer because the symptoms are uncertain and can disappear. Damayanti et al. (2023) stated that the epidemiological prevalence of TMD is that 40-75% of the general population is likely to experience at least one symptom of TMD, but only 3-7% are reported to have received treatment, with the largest number being adults to middle-aged individuals ranging from 20-45 years old and generally female. The prevalence of TMD in women is greater than in men because women tend to have complex physiological characteristics and hormonal variations, such as the hormone estrogen. Najma et al. (2014) stated that 59 out of 100 patients in the dental clinic of Ulin Hospital, Banjarmasin, had TMD disorders. The percentage of TMD according to gender in patients who came to the dental clinic of Ulin Hospital was 41% in men, while female patients were 59%.[5,10,11]

Ulin Banjarmasin Regional General Hospital is a class A teaching hospital in Banjarmasin City, South Kalimantan. This hospital has complete medical facilities and is the largest referral hospital in South Kalimantan and Central Kalimantan. One of Ulin Regional Hospital's facilities is a dental X-ray, located in the radiology installation section of Ulin Banjarmasin Regional Hospital. Gusti Hasan Aman Dental and Oral Hospital is a regional hospital that provides dental and oral health services using modern and the best technology and has superior human resources. Gusti Hasan Aman Hospital is a pioneer of the leading teaching hospital licensed as a teaching hospital with facilities for education, research, and community service.[5,11–13]

This study aimed to determine the shape and position of the condyle in Kennedy class I, II, III, and IV patients using panoramic radiography at Ulin Regional Hospital and Gusti Hasan Aman Banjarmasin General Hospital. This research focused on Kennedy classes I, II, III, and IV so the specification of changes from edentulous teeth can be identified.

MATERIALS AND METHODS

The type of research design used is descriptive research with a cross-sectional design obtained from secondary data from patient examinations using panoramic radiography techniques at the radiology installation of Ulin Hospital and Gusti Hasan Aman Banjarmasin Hospital. Descriptive research is a method used to see a picture of a phenomenon that occurs in a specific population without treating the variables.[14,15]

A cross-sectional design is used to conduct research, and data collection and analysis are carried out only once during one study. Descriptive research is a cross-sectional approach to conduct descriptions without in-depth analysis.[14,16]

The following are the inclusion criteria in this study: partially edentulous panoramic radiograph of the upper and lower jaw with Kennedy classification class I, II, III, IV period January 2018–January 2024 with good quality evaluation, panoramic radiographs with patients aged 30-70 years, complete patient data in the form of name and age, anatomical landmarks such as the inferior and posterior borders of the mandible, as well as the condyle area are visible. Here are the exclusion criteria in this study: panoramic radiograph in the presence of a fracture of the lower jaw, panoramic radiograph in the presence of diseases affecting the mandible such as odontogenic cysts, odontogenic and non-odontogenic tumors, osteomyelitis, ankylosis/hypoplasia/hyperplasia of the temporomandibular joint.

This type of research is descriptive with a cross-sectional design. Sampling used a purposive sampling technique. This research has received ethical approval from the ULM Banjarmasin Faculty of Dentistry Health Research Ethics Committee with No. 145/KEPKG-FKGULM/EC/XI/2023. The population of this study consisted of patient data and panoramic radiographs with Kennedy classification at Ulin Regional General Hospital and Gusti Hasan Aman Banjarmasin General Hospital taken in the period January 2018-January 2024.

The following are the inclusion criteria in this study: partially edentulous panoramic radiograph of the upper and lower jaw with Kennedy classification class I, II, III, IV period January 2018–January 2024 with good quality evaluation, panoramic radiographs with patients aged 30-70 years, complete patient data in the form of name and age, anatomical landmarks such as the inferior and posterior borders of the mandible, as well as the condyle area are visible. Here are the exclusion criteria in this study: panoramic radiograph in the presence of a fracture of the lower jaw, panoramic radiograph in the presence of diseases affecting the mandible such as odontogenic cysts, odontogenic and non-odontogenic tumors, osteomyelitis, ankylosis/hypoplasia/hyperplasia of the temporomandibular joint.

The sampling technique used in this study was the non-random sampling method (non-probability sampling) with the purposive sampling method, namely the sample selected for the study based on inclusion and exclusion criteria. The sample size in this study was 120 samples. The variables studied in this study were the shape and position of the condyle from the results of panoramic radiographs in patients with partial tooth loss classified based on Kennedy's classification class I, II, III, IV. This study did not use independent or dependent variables because there was no proof of the hypothesis regarding the relationship or strength of one variable to another. The data that had been collected was then processed and analyzed—data processing using the MS Excel application (Microsoft Office Excel). The data analysis used in this study was descriptive statistical analysis.

RESULTS

The description of the condyle shape of Kennedy classification patients from panoramic radiography results at Ulin Banjarmasin Hospital and Gusti Hasan Aman Banjarmasin General Hospital from January 2018-January 2024 on the right and left sides can be seen in Table 1. Namely, Kennedy classification class I has a round shape with 20 condyle shapes (33.3%), and the majority in class I-II have eight condyle shapes. Kennedy classification class II has the most round shapes with 22 condyle shapes (36.7%). The majority in classes II-I and II-II have the same number of eight condyle shapes. Kennedy classification class III has the most round shapes, with 28 condyle shapes (46.7%), and the majority in class III-III has 11 condyle shapes. Kennedy classification class IV has the most round shapes with 22 condyle shapes (36.7%). The majority in classes IV-II and IV-III have the same number of eight condyle shapes. The most common condylar shape on the right and left sides were round, with a total of 92 condylar shapes (38.3%) from a total of 240 condylar shapes from 120 patients, the majority of which were class III with a total of 28 patients (46.7%). This research was observed by a Dentomaxillofacial Radiology Specialist with several repetitions in the calculations.

The description of the condyle position of Kennedy classification patients from panoramic radiography at Ulin Banjarmasin Hospital and Gusti Hasan Aman Banjarmasin General Hospital for the

Table 1. Description of the Condyle Shape of Kennedy Classification Patients Class I, II, III, IV Period January 2018-January 2024 Right and Left Sides

Kennedy Classification		n	Condyle Shape									Total
Upper	Lower		Right and Left Side									
Class			R	A	P	C	F	O	E	FG	S	
I	I	20	6	0	3	0	3	0	0	3	5	20
	II	20	8	0	1	0	0	0	0	9	2	20
	III	20	6	3	3	0	1	0	1	5	1	20
Total		**60**	**20**	**3**	**7**	**-**	**4**	**-**	**1**	**17**	**8**	**60**
%		**100**	**33,3**	**5**	**11,7**	**0**	**6,7**	**0**	**1,7**	**28,3**	**13,3**	**100**
II	I	20	8	1	0	0	1	1	0	6	3	20
	II	20	8	0	2	0	2	2	0	2	4	20
	III	20	6	0	1	1	1	3	0	5	3	20
Total		**60**	**22**	**1**	**3**	**1**	**4**	**6**	**-**	**13**	**10**	**60**
%		**100**	**36,7**	**1,7**	**5**	**1,7**	**6,7**	**10**	**0**	**21,7**	**16,7**	**100**
III	I	20	8	0	0	0	3	0	1	5	3	20
	II	20	9	1	0	0	2	0	0	7	1	20
	III	20	11	0	1	0	3	1	0	4	0	20
Total		**60**	**28**	**1**	**1**	**-**	**8**	**1**	**1**	**16**	**4**	**60**
%		**100**	**46,7**	**1,7**	**1,7**	**0**	**13,3**	**1,7**	**1,7**	**26,7**	**6,7**	**100**
IV	I	20	6	2	4	0	2	2	2	2	0	20
	II	20	8	0	2	0	3	2	0	2	3	20
	III	20	8	1	1	3	1	3	0	1	2	20
Total		**60**	**22**	**3**	**7**	**3**	**6**	**7**	**2**	**5**	**5**	**60**
%		**100**	**36,7**	**5**	**11,7**	**5**	**10**	**11,7**	**3,3**	**8,3**	**8,3**	**100**
Amount		240	92	8	18	4	22	14	4	51	27	240
Percentage (%)		100	38,3	3,3	7,5	1,7	9,2	5,8	1,7	21,3	11,3	100

*Notes: R: Round; A: Angled; P: Pointed; C: Crocked Finger; F: Flat; O: Osteophyte; E: Erosion; FG: Flattening; S: Sclerosis

Table 2. Condylar Position of Kennedy Classification Patients Class I, II, III, IV Period January 2018-January 2024 Right and Left Side

Kennedy Classification		n	Condyle Position				
Upper	Lower		Right and Left Side				
				Abnormal Position			
Class	Class		Normal	Heading to the Anterior	Heading to the Posterior	Heading to the Superior	Total
I	I	20	6	8	5	1	20
	II	20	4	11	1	4	20
	III	20	3	11	3	3	20
Total		**60**	**13**	**30**	**9**	**8**	**60**
Percentage (%)		**100**	**21,7**	**50**	**15**	**13,3**	**100**
II	I	20	2	12	5	1	20
	II	20	0	12	7	1	20
	III	20	1	13	2	4	20
Total		**60**	**3**	**37**	**14**	**6**	**60**
Percentage (%)		**100**	**5**	**61,7**	**23,3**	**10**	**100**
III	I	20	3	2	13	2	20
	II	20	4	5	10	1	20
	III	20	4	9	7	0	20
Total		**60**	**11**	**16**	**30**	**3**	**60**
Percentage (%)		**100**	**18,3**	**26,7**	**50**	**5**	**100**
IV	I	20	2	10	8	0	20
	II	20	4	7	7	2	20
	III	20	2	10	6	2	20
Total		**60**	**8**	**27**	**21**	**4**	**60**
Percentage (%)		**100**	**13,3**	**45**	**35**	**6,7**	**100**
Total		240	35	110	74	21	240
Percentage (%)		100	14,6	45,8	30,8	8,8	100

period January 2018-January 2024 on the right and left sides can be seen in Table 2, namely, Kennedy classification class I with the most condyle positions being in an abnormal position leading to the anterior with a total of 30 condyle bones (50%) the majority being in class I-II and I-III with each class having the same number of 11 condyle bones. Kennedy classification class II has the most condyle positions, being in an abnormal position leading to the anterior, with 37 condyle bones (61.7%), the majority being in class II-III, with 13 condyle bones. Kennedy classification class III has the most condyle positions, being in an abnormal position leading to the posterior with 30 condyle bones (50%), the majority being in class III-I with a total of 13 condyle bones. Kennedy Classification Class IV, with the most condylar positions, is in an abnormal position that leads to the anterior with 27 condylar bones (45%). The majority are in classes IV-I and IV-III. Each class has the same number of 10 condylar bones. The most significant number of right and left condylar positions of all classes (I, II, III, IV) is an abnormal condylar position that leads to the anterior, with a total of 110 condylar bones (45.8%) of the total 240 condylar bones observed, the majority are in class II with a total of 37 condylar bones (61.7%) whose position is abnormally leading to the anterior.

DISCUSSION

Most of the condyle shapes of Kennedy class I, II, III, and IV patients through panoramic radiography examination results at Ulin Hospital and Gusti Hasan Aman Banjarmasin General Hospital are round with 92 (38.3%). The second most common shape is flattening, with 51 (21.3%) from a population of 120 patients with a total of 240 condyles observed. In contrast, the least common shapes are crooked fingers and erosion, each with four (1.7%). Changes in the condyle change significantly during growth. Variations in the shape of the condyle can occur because the condyle can adjust to the shape of the glenoid fossa during its development.[6,17–20]

The round shape is the most common condylar shape found in Kennedy class I, II, III, and IV patients through panoramic radiography results at Ulin Banjarmasin Hospital and Gusti Hasan Aman General Hospital. Based on previous studies, namely Gupta et al., as much as 79%, Khanal 63.6%, Maqbool et al. 60.6%, and Sonal et al. 60%. This can be caused by the loss of occlusal contact or an imbalance in the patient's occlusion, which disturbs the stability of the jaw arch and increases the occurrence of degenerative disorders.[14,16,18,19,21–23] The changes in the shape of the condyle are due to the patient losing some teeth for a long period, allowing for increased morphological remodeling of the TMJ skeletal structure. This follows previous research, which states that abnormalities in the TMJ can cause several changes to the surface of the condyle.[17–19,21,23–27]

The changes in the condyle shape are due to the patient losing some teeth for an extended period, allowing for increased morphological remodeling of the TMJ skeletal structure. This follows previous research, which states that abnormalities in the TMJ can cause several changes to the surface of the condyle.[22,26–29]

The occurrence of abnormal condylar changes is caused by each patient experiencing a different development process and having bad habits, which trigger abnormal condylar changes. In this study, the most common abnormal condylar change was flattening. Flattening is caused by the patient experiencing partial tooth loss and causing the patient to chew more with one side so that one side changes shape to become pathological. Excess joint load causes the condylar to change shape by increasing the surface area of the condylar in contact with the articular surface so that the load received is lighter.[22,28,29]

Diernberger et al. (2008) stated that more than 45% of the general population has a habit of chewing on one side. Some are more comfortable chewing unilaterally because of a cavity that hurts, a tooth that hurts when chewing, habits, tooth loss, and others. Bad habits of chewing on one side can cause unbalanced occlusal fatigue, changes in the occlusal plane, mandibular deviation when closing and opening the mouth, changes in bone structure, decreased temporomandibular joint function, headaches, and affect hard tissue, tooth-supporting tissue such as alveolar bone, periodontal ligament, gingiva or other oral mucosa. These conditions can result in excessive biomechanical pressure distribution on one side of the joint only if left untreated and unbalanced remodeling occurs, which will cause damage to the condyle.[22,30–32]

The condyle position in Kennedy class I, II, III, IV patients through panoramic radiography results at Ulin Hospital and Gusti Hasan Aman Banjarmasin General Hospital is mostly directed anteriorly, namely 110 (45.8%) and the second most directed posteriorly as many as 74 (30.8%) while the condyle position in Kennedy class I, II, III, IV patients is least directed superiorly, namely 21 (8.8%). The normal position of the mandibular condyle is in the glenoid fossa, but there are several variations in the position of the condyle, namely directed posteriorly, anteriorly, superiorly, and interiorly. This is because the condyle can adjust to the shape of the glenoid fossa during its development. Asymptomatic joints can experience disc shifting; therefore, variations in the normal condyle position can be found. However, joints with disc positions that do not shift (normal) can be found to have variations in the position of the condyle. [8,9,17,20] The second most common condyle position on panoramic radiographs is posterior. This is indicated by the anterior space being wider than the posterior space and the posterior space being narrower. Normal development of the ramus and condyle of the mandible can cause the adult mandible to move downward and forward, causing facial movement in the anterior and posterior directions. Kurita et al. (2001) where, in their study on patients with internal derangement with reduction, showed a tendency for the condyle to shift more posteriorly.[8,33,34]

The condyle is located above the narrow neck of the mandible, 15 to 20 mm from side to side and eight to 10 mm from front to back. According to Rosado et al. (2021), there is a significant decrease in bone volume in the glenoid fossa in edentulous patients. Further investigations conducted by Chen et al. (2022) revealed that tooth loss, even unilaterally, can cause a decrease in condylar bone volume in an in vivo experimental model. Therefore, the duration of tooth loss can affect changes in the morphology of the condylar process and its position in the TMJ.[17,28,33–36]

The weakness of this research is that the Data used is secondary data. The hope for the future is to use primary data. Then, the data can give the best results from anamnesis and physical examinations in the patients to evaluate the correlation of edentulous teeth in Kennedy classification with habit from patients and many causes that can be a risk factor for TMD.

CONCLUSION

Based on the research that has been done, the conclusion in the frequency distribution of the shape and position of the condyle of patients with Kennedy classification class I, II, III, IV was the round shape as the most common condyle shape experienced by patients which is one of the normal condyles shapes, and an abnormal position of TMJ condition pointing anteriorly. The existence of variations or changes in the shape and position of the condyle can be caused by the loss of some teeth for too long a period, increasing morphological remodeling of the TMJ skeletal structure, especially the glenoid fossa.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article. . This research has received ethical approval from the ULM Banjarmasin Faculty of Dentistry Health Research Ethics Committee with No. 145/KEPKG-FKGULM/EC/XI/2023. All procedures conducted were in accordance with the ethical standards.

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CASE REPORT

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Analysis of ameloblastic fibroma lesion on panoramic radiograph: a case report

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ABSTRACT

Objectives: This case report aims to present a case of ameloblastic fibroma, an odontogenic tumor, and to describe its characteristic radiographic features as observed on a panoramic radiograph.

Case Report: A 28-year-old woman presented to the RSGM FKG Unpad with a referral for evaluation of a jaw swelling. According to the patient's medical history, the swelling had gradually appeared over the past two years. While it was not painful, it caused discomfort, prompting her to seek medical attention. Upon examination, the lesion was found in the posterior region of the mandible, and further diagnostic imaging was recommended to determine the extent and nature of the lesion. Ameloblastic fibroma of the jaw is a benign, relatively rare, mixed odontogenic tumor whose epithelial and mesenchymal components are neoplastic. This tumor is usually diagnosed in the first and second decades of life (72.4%), when odontogenesis has been completed (80% of cases), and mainly affects the mandible. In this case, the lesion was diagnosed in the second decade of life, and occurred in the posterior region of the mandible.

Conclusion: Ameloblastic fibroma is a benign odontogenic mixed tumor, although rarely ameloblastic fibroma can recur and develop into malignancy. The aim of this case report is to analyze the radiographic appearance of the lesion with information from the history and clinical signs to establish a correct radiodiagnosis.

Keywords: *Ameloblastoma, ameloblastic fibroma, panoramic radiograph*

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INTRODUCTION

Ameloblastoma and other odontogenic tumors, such as ameloblastic fibroma and ameloblastic fibro-odontoma, are benign neoplasms that arise from the odontogenic apparatus, which includes the tissues responsible for tooth development. These tumors are classified by the World Health Organization (WHO) based on the type of tissue involved in their formation. The classification includes three primary categories: 1) tumors derived from epithelial tissue, such as ameloblastoma, 2) mixed odontogenic tumors, which include both epithelial and ectomesenchymal components, such as ameloblastic fibroma and ameloblastic fibro-odontoma, and 3) tumors that originate from ectomesenchymal tissue alone. Understanding the classification of odontogenic tumors is essential for accurate diagnosis and treatment planning.[1,2]

Ameloblastic fibroma is a rare mixed odontogenic tumor, accounting for approximately 2% of all odontogenic tumors. This tumor predominantly affects patients during the first two decades of life, with no clear gender predilection. The mandible is the most commonly involved site, with 80% of reported cases localized to the premolar and molar regions.[3,4] While it is a benign entity, the potential for recurrence and, in rare instances, malignant transformation necessitates careful monitoring and management.

Radiographic examination plays a crucial role in differentiating odontogenic tumors, including ameloblastic fibroma, from other lesions. One key aspect of this differentiation is the assessment of the internal structure of the lesion, which can be classified into three main types: completely radiolucent, completely radiopaque, and mixed density, which shows a combination of both features.[4,5] Ameloblastoma, ameloblastic fibroma, and ameloblastic fibro-odontoma may exhibit overlapping radiographic features, which can complicate the diagnostic process. As a result, these lesions are often considered in a differential diagnosis.

Radiographically, ameloblastic fibromas typically present as either unilocular or multilocular radiolucencies with well-defined sclerotic borders. While unilocular lesions are generally asymptomatic, multilocular lesions are more likely to present with noticeable jaw swelling. In many instances, ameloblastic fibromas are discovered incidentally during routine dental or radiographic examinations.[6] Because of the similarity in appearance between ameloblastic fibromas and other odontogenic lesions, such as ameloblastomas, dentigerous cysts, odontogenic keratocysts, central giant cell granulomas, and histiocytosis, accurate differentiation is crucial for appropriate treatment.[7] Additionally, if atypical mitoses or mitotic cells are present within the lesion, malignancy, such as ameloblastic fibrosarcoma, should be considered as part of the differential diagnosis.[8] This makes careful histological evaluation and radiographic assessment essential in managing these tumors.

CASE REPORT

A 28-year-old woman presented at the RSGM FKG Unpad with a referral for evaluation of a swelling in her jaw. According to the patient's anamnesis, the swelling had gradually appeared over the past two years. It was not painful but caused some discomfort. The patient reported that the swelling had remained stable in size but had not shown any significant improvement. Upon intraoral examination, a mass was palpated in the lower right region of the posterior mandible. The mass was non -tender to palpation, and the surrounding mucosal tissues appeared normal. Extraoral examination revealed noticeable swelling in the angular area of the right mandible, extending to the inferior border, resulting in mild facial asymmetry. This external swelling was evident and palpable, contributing to the patient's visible facial distortion (Figure 1).

To further investigate the lesion, a panoramic radiograph was taken. The radiograph revealed a multilocular, well-defined, septate radiolucent lesion in the posterior region of the right mandible, extending from the distal aspect of tooth 45 to the angle of the mandible, and reaching the inferior border. The lesion demonstrated a corticated outline, a feature characteristic of benign odontogenic tumors. There was also significant bone involvement, as the lesion caused resorption of the mesial root of tooth 48 and displaced the surrounding structures, including the mandibular ramus, in an oblique direction (Figure 2). These

Figure 1. Intraoral and extraoral view of the patient

Figure 2. Panoramic radiograph examination of the patient

radiographic features suggested a mixed odontogenic tumor, with a differential diagnosis that included ameloblastoma and ameloblastic fibro -odontoma due to their similar appearance on imaging.

Based on the patient's history, the results of the intraoral and extraoral examinations, and the radiographic findings, a preliminary radiodiagnosis of ameloblastic fibroma was made. The differential diagnosis included ameloblastoma, which also presents as a multilocular radiolucent lesion, and ameloblastic fibro-odontoma, which may show similar radiographic features. The clinical and radiographic findings were further supported by the lesion's location and the patient's age, aligning with the typical presentation of ameloblastic fibroma. These findings indicated the need for further histopathological evaluation to confirm the diagnosis and guide appropriate treatment.

DISCUSSION

Ameloblastic fibroma is a benign, relatively rare mixed odontogenic tumor that comprises both epithelial and mesenchymal neoplastic components. This tumor typically occurs in the first and second decades of life, with approximately 72.4% of cases diagnosed during these years. It predominantly affects the mandible, with 80% of cases occurring after odontogenesis has been completed. In this particular case, the lesion was identified in the patient's second decade of life and located in the posterior region of the mandible. Although ameloblastic fibromas most commonly affect the mandible, a few cases have been reported in the maxilla, highlighting the potential for variable presentation across different regions of the jaw.[6,7-8]

Ameloblastic fibroma generally does not present with specific clinical signs or symptoms. It is often discovered incidentally during routine radiographic examinations, when it may be mistaken for cysts or other odontogenic tumors. In this case, the patient did not report concerns regarding the absence of the lower right molar tooth but instead experienced difficulty chewing due to the mass. This aligns with the typical presentation of ameloblastic fibroma, where the most common complaint is painless swelling, though some patients may also notice delayed or impaired tooth eruption.[9]

Radiographically, ameloblastic fibromas typically appear as well-defined, unilocular or multilocular radiolucent lesions, often with corticated borders. In fact, more than 50% of ameloblastic fibromas are associated with unerupted or malpositioned teeth, further supporting the odontogenic origin of the tumor. When the lesion exhibits a multilocular radiographic pattern, internal septa may appear radiopaque, adding complexity to the diagnosis. The effects on surrounding tissue can include displacement of neighboring teeth and extension of the lesion into adjacent regions of the jaw, such as the buccal or lingual aspects. Although benign, if left untreated, ameloblastic fibroma has the potential to develop into malignancy, underscoring the importance of early intervention.[6,10,11]

In terms of size, multilocular patterns are often seen in larger tumors, which account for approximately 75% of cases, while smaller lesions, typically measuring less than 4 cm, tend to exhibit a unilocular radiolucent appearance. This case reflects the more common presentation of a smaller lesion with a unilocular pattern. Given the overlapping radiographic features of ameloblastic fibromas and other odontogenic lesions, differential diagnosis is essential. Ameloblastoma, odontogenic myxoma, dentigerous cyst, odontogenic keratocyst, central giant cell granuloma, and histiocytosis must all be considered when evaluating a lesion with similar radiographic features.[11]

The pathogenesis of ameloblastic fibroma remains unclear, with much still unknown about the interactions between the epithelial and mesenchymal components. The tall, columnar ameloblast-like cells in the epithelial component, which are typically too mature to influence ectomesenchymal cells, raise questions about the mechanisms driving the tumor's development. Moreover, it is not entirely understood why the induction of odontoblastic differentiation is absent in ameloblastic fibroma, despite its odontogenic origin. Immunohistochemical analysis has provided some insights into the molecular characteristics of ameloblastic fibromas, revealing positive staining for cytokeratin in the odontogenic epithelium, tenascin for mesenchymal tissue, and vimentin for basement membrane components. These findings suggest that ameloblastic fibromas most commonly develop during the early stages of odontogenesis, supporting the notion that the lesion's development is rooted in a disturbance in normal tooth development.[11]

CONCLUSION

Ameloblastic fibroma is a benign odontogenic mixed tumor, although in rare cases, it can recur and potentially develop into malignancy. The aim of this case report is to analyze the radiographic appearance of the lesion in conjunction with the patient's history and clinical signs in order to establish an accurate radiodiagnosis.

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FOOTNOTES

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CASE REPORT

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Odontogenic sinusitis due to radix perforation into the maxillary sinus on CBCT radiograph: a case report

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ABSTRACT

Objectives: The purpose of this article was to provide an overview and examination guide in identifying odontogenic sinusitis due to radix perforation into the maxillary sinus by dental action or iatrogenic in dentistry using the CBCT modality.

Case Report: A 33-year-old female patient presented to the Radiology Installation of RSGM Andalas University with a referral for CBCT, following a diagnosis of odontogenic sinusitis. According to the patient's medical history, she had been experiencing headache and dizziness for five months after a tooth extraction. The CBCT scan revealed remnants of a tooth root (radix) perforating into the right maxillary sinus, surrounded by a radiopaque intermediate area. Sinus perforation is a known occurrence in dentistry, and it requires thorough diagnostic imaging for proper evaluation. The tooth root remnants are typically located in the premolar and molar regions, near the base or medial wall of the sinus. The size of the tooth fragments within the sinus can be precisely measured, and the relationship of the remaining fragments to the maxillary sinus anatomy can be clearly defined. This detailed information enables clinicians to assess the extent of the lesion and its impact on surrounding structures, allowing for the development of an appropriate treatment plan for the patient.

Conclusion: CBCT is a very adequate modality for supporting the examination of cases of residual tooth roots perforated to the sinuses because it can provide detailed information about the position, size, and relationship with the surrounding anatomy.

Keywords: *Cone-beam computed tomography, perforation, radix, odontogenic sinusitis*
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INTRODUCTION

Odontogenic maxillary sinusitis is an inflammation of the sinuses that can be caused by factors related to the teeth such as apical or periodontal lesions that occur in the posterior teeth of the upper jaw or the remaining radix. If obstruction occurs in the ostium sinuses, there is an increase in pressure in the sinus cavity which causes mucosal swelling and complaints in patients. Odontogenic maxillary sinusitis is a frequent complication of dental procedure. It is estimated that the incidence of maxillary sinusitis due to odontogenic factors is around 25-40%. It is generally caused by periapical sepsis, and iatrogenic at the time of tooth extraction.[1]

Complications in various procedures in dentistry are conditions that is difficult to avoid.[1] During tooth extraction, radix or part of the tooth can be pushed into the maxillary sinuses.[1,2,3] In general, the apex of the premolar teeth and molar of the upper jaw is indeed close to the base of the maxillary sinus. Based on Bajoria's research data, as many as 74.9% of dental apical cases touch the base of the sinuses, 16.9% are adjacent to the base of the sinuses, and as many as 8.2% of dental apical cases are in the sinuses.[3]

There are several ways to diagnose and determine the position of teeth that have moved into the maxillary sinuses. However, CBCT is a fairly good modality in assessing complex conditions because it can provide a large scope to visualize the entirety of the sinus and detailed information about the size, position, shape, and relationship of anomalies or lesions to the anatomy of the maxillofacial area. CBCT is an option if the simple modality cannot provide complete information to make a proper treatment plan for the patient.[4,5,6] This article aims to provide an overview and examination guide in identifying odontogenic sinusitis due to radix perforation into the maxillary sinus due to dental or iatrogenic procedures in dentistry using CBCT modalities.

CASE REPORT

A 33-year-old female patient came to the Radiology Installation of RSGM Andalas University with a referral for CBCT. From the anamneses, it is known that the patient had performed the extraction of the first right molar tooth about 3 months ago. After the tooth extraction, it was found that there were fragments of tooth roots that had not been found. The clinician then referred the patient for a CBCT photo as a supporting examination of the patient. After the extraction procedure, patients often feel headaches and dizziness.

From the CBCT radiographic examination, it was found that there was a disconnection of basic cortical continuity of the dextra maxillary sinus in the region of the palatal root socket of tooth 16 (Figure 1). There is a radiopaque imaging on the maxillary sinus dextra similar to the image of radix in the tooth area. This residual fragment of radix intersects with the medial wall of the maxillary sinuses. The remaining fragment of this radix has a size of ± 8 mm. In the maxillary sinus area, there is an intermediate radio image on the wall and base of the sinus. The intermediate radio area covers the socket area until one-third of the inferior area of the maxillary sinus. A radio intermediate image can be seen in the area around the remaining tooth roots in the maxillary sinus dextra (Figure 2).

DISCUSSION

Teeth or dental radix, is a foreign object that is often found in the maxillary sinuses. The presence of radix in the maxillary sinuses can occur due to iatrogenic in dental practices.[2,7] The presence of teeth in these sinuses is also a result of the neglect of clinicians about the need for X-rays before tooth extraction, especially in molar and upper premolar teeth related to the anatomically maxillary sinuses.[2,3,8,9]

Various variations in the anatomy of the head and neck require a more optimal examination due to the limitations of examination with 2D radiograph.[8] In simple cases, the use of panoramic photos can already provide quite good information.[10] But in more complex cases, the use of CBCT is the right choice. Accurate information is needed for cases of teeth or radix perforations to the sinuses, so that clinicians can create minimally invasive treatment plans.[2] In this case, the patient requires a sufficiently adequate examination to identify the position of the roots that have perforated into the maxillary sinuses. The use of CBCT is the golden standard for identifying, diagnosing, and evaluating the details of dental structures that may be involved.

The perforation of the maxillary sinuses appears to be more frequent, especially when clinicians

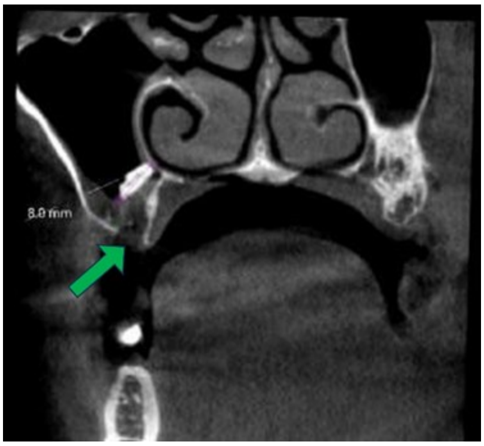

Figure 1. CBCT coronal view of cortical discontinuity at palatal socket (arrow)

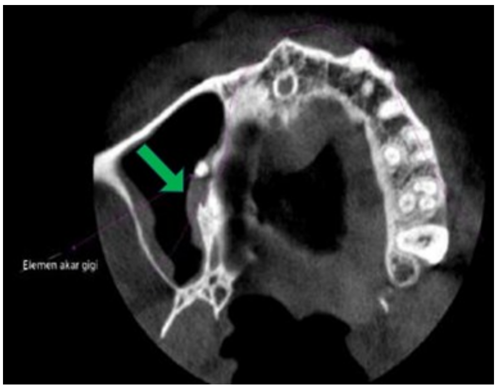

Figure 2. CBCT axial view of radix intersects with the medial wall of the maxillary sinuses and radio intermediate area (arrow)

Figure 3. Oroanthral communication on dental socket

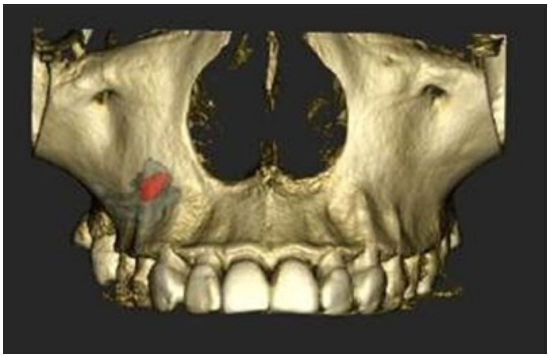

Figure 4. Radix in the medial wall of the right maxillary sinus (3D view)

perform extractions of the maxillary molar or premolar.[2,11] Based on Seigneur's systematic research, 159 cases of teeth being pushed into the sinuses, 72% are moral teeth, 7% are premolar teeth, and 21% cannot be specified. Of all these cases, 26% were found to involve palatal roots.[2] In this case, the occurrence of radix or tooth fragments in the sinuses also occurs in molar and premolar teeth on molar and premolar regio (Figure 3). This is due to the location of the tooth which is adjacent to the sinuses, and tooth fragments or radix are generally at the base of the sinuses, due to gravity. Sometimes it can also be in the submucosa or medial or lateral wall of the sinuses.[2,12,13]

CBCT is the appropriate modality for examining cases of teeth or radix that perforate the sinuses. CBCT can provide a detailed picture of the case. CBCT provides information about the location of tooth elements or radix within the sinuses.[4,5] Varied anatomical images of the sinuses require adequate imaging.[14] CBCT images provide sagittal, coronal, axial and 3D views that are very helpful for obtaining complete information. In this case, from a coronal point of view, it is known that the position of the radix is on the medial wall of the maxillary sinus dextra (Figure 4). This information will make it easier for the clinician to determine the direction of tooth fragment placement, as CBCT guide will help clinician to estimate the distance where the fragment position is located, which can be shown in a sagittal view.

How to distinguish healthy sinuses and radiologically infected sinuses is quite easy considering that the sinuses area space that contains air. In healthy sinuses, radiologically it will provide a clear and defined radiolucent. In diseased sinuses, clinicians will find clouding/radio intermediate conditions, thickening of the mucosa, or fluid accumulation.[3] In the early stages, generally the image of the sinus is only in the form of sinus radiolucent and radiopaque that resembles teeth or radix. In the advanced or chronic stage, the sinuses can show a radio intermediate image because there is already an infectious process in the sinuses as a result of the presence of teeth in the sinuses and the presence of oroantral communication.[15,16,17] The CBCT image shows the presence of radio intermediate images around the radix in the sinuses, which indicate that an infection has occurred in the sinuses (Figure 1). The CBCT also provides detailed information about the size, number, and shape of the tooth fragments or radix present in the sinuses. In this case, there is one radix with ± 8 mm length. This information can make it easier for clinicians to take radix and minimize surgical wounds because the location and position of the radix are known.

However, negligence in the tooth extraction procedure that causes the entry of the remaining tooth structure into the maxillary sinus, should have been avoided. As a preventive measure that can be recommended to dentists as clinicians is to carry out preoperative actions and radiological examinations in the form of periapical or panoramic. Interpretation of the anatomy, the number of roots, and their relationship to the maxillary sinus base can avoid complications at the time of retraction.[2] Consideration to carry out a radiographic examination before tooth extraction is important to do, because it can determine the treatment plan to be carried out and high vigilance in cases that have great potential for complications, especially in cases of teeth adjacent to the maxillary sinuses.[9,18]

CONCLUSION

Cases of odontogenic sinusitis due to radix perforating to the maxillary sinuses require adequate examination. CBCT is the right choice in this case because it can provide complete information of the shape, size, position, and relationship of the radix to the surrounding anatomy in the maxillary sinuses. Complete information is needed for clinicians to make appropriate and efficient treatment plans for patients.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article. Informed consent was obtained from the patient for being included in this case report.

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REVIEW ARTICLE

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The role of radiographic imaging and finite element analysis in evaluating occlusal loads and stress distribution in the periodontal ligament

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ABSTRACT

Objectives: Biomechanical behavior analysis of the periodontal ligament (PDL) under various loading conditions is essential for understanding the impact of occlusal force distribution. A comprehensive understanding of this aspect is fundamental, and radiographic examination is a crucial modality for evaluating periodontal health. This review aims to illustrate the role of radiographic examination in influencing dental prognosis through the use of Finite Element Analysis (FEA) to assess occlusal load and stress distribution in PDLs.

Review: Radiographic imaging techniques are critical for assessing the extent of occlusal trauma and its impact on the periodontal ligament and surrounding structures. Modalities such as conventional radiography, cone-beam computed tomography (CBCT), and micro-computed tomography (micro-CT) are commonly used to evaluate occlusal load. Studies have demonstrated that a balanced occlusal scheme results in a more uniform stress distribution, while an unbalanced scheme leads to localized stress concentrations, increasing the risk of periodontal damage. FEA has emerged as a powerful tool for simulated and visualizing stress patterns in the PDL and quantitatively calculating stresses and deformations in the periodontium. Technological advances in imaging, when applied in conjunction with finite element computational techniques, have shown that oblique loading results in higher stress concentrations compared to vertical loading, particularly in the PDL of mandibular first molars. These higher stresses, often observed in the cervical and apical regions, highlight the potential for more significant PDL damage, making it useful for evaluating bone loss and PDL integrity. for eligibility and completeness of journals.

Conclusion: Integration of advance radiographic imaging with FEA has significantly enhanced the understanding of occlusal load and stress distribution in the periodontal ligament. This advancement has propelled the field of periodontal biomechanics, offering very valuable insights into PDL's biomechanical behavior as it responds to varying occlusal loads, to optimize outcomes in periodontal and orthodontic care.

Keywords: *Finite element analysis, periodontal ligament, stress distribution, occlusal trauma*

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INTRODUCTION

Periodontium has its own ability to respond to the stress produced by occlusal forces within the tooth and supporting structures. Regarding the occlusal force loads, the adaptive capacity of the periodontal structures varies from individual to individual.[1] Periodontal ligament (PDL) is a specialized connective tissue of the periodontium that plays a critical role in maintaining the health and functionality of teeth, as well as the maintenance and health of the periodontium by connecting the tooth to the alveolar bone. It is not only a supportive structure but also a sensory apparatus that provides proprioceptive feedback to the central nervous system. It works as a shock absorber, distributing occlusal loads and stress to prevent damage to the tooth structure and surrounding bone, anchoring teeth within the alveolar bone, and absorbing occlusal loads to prevent damage to dental and periodontal structures.[2,3]

The PDL contains a network of collagen fibers, blood vessels, and nerves, providing structural support and sensory feedback.[2,3] The PDL's ability to adapt to mechanical forces is vital for maintaining periodontal health. Abnormal occlusal loads can lead to alterations in the PDL, resulting in inflammation, resorption of alveolar bone, and eventually, tooth mobility or loss.[4,5] Analysing the biomechanical behavior of the PDL under various loading conditions is very important, especially for optimizing dental treatments, such as prosthodontics and orthodontics. Understanding how the occlusal forces are distributed is crusial for the diagnosis and treatment of periodontal and dental circumtances. The stress distribution within the PDL under occlusal loads is vital for assessing the biomechanical environment of the periodontium, particularly in response to varying occlusal forces and their potential pathological consequences. These occlusal forces may vary based on the somatic and physical changes in the individual toward the PDL reaction even in the same individual, from time to time.[1,6]

Radiographic imaging has become an indispensable tool in evaluating the PDL, as it provides detailed visualizations of the structures involved and allows for assessing occlusal loads and stress distribution.[7,8] Finite Element Analysis (FEA) become a powerful tool for simulating stress distribution within the PDL, providing detailed insights into the effects of occlusal forces, using geometry data obtained from radiographic imges to create a three dimensional model, for example, the PDL space widening on the radiography, that may indicate local stress concetration, can be further analysed using FEA to predict the area of stress distribution or PDL's potensial damage area. Shetty at. al study using CBCT data and 3D Finite Element Model (FEM) to evaluate stress distribution of maxilla molar PDL under different occlusal loading conditions, showed that oblique loading resulted in higher stress concentrations in cervical and apical regions of the PDL compared to vertical loading. These tensile stresses, can obstruct blood flow, resulting in PDL damage that can lead to other supporting structures damage or further more become traumatic occlusion. This review aims to summarize recent advancements in the role of radiographic appearance in understanding the impact of occlusal forces and understanding mechanical behaviour of the PDL and how this knowledge can influence the prognosis of teeth as well as the FEA applications for studying occlusal loads and stress distribution in the PDL.[9–11]

REVIEW

Radiographic examinations are indispensable tools in the evaluation of periodontal health and the assessment of occlusal forces. They provide a visual representation of the bone and PDL, allowing for the detection of pathological changes. Radiographic techniques, including periapical, bite-wing radiographs and panoramic, are commonly used to assess the bone level and the condition of the PDL space. Image of excellent quality is necessary because the fine details are required for interpretation of the periodontal tissues, in the example it can clearly show a radiolucent line along the mesial-distal aspects of the teeth between the roots and lamina dura is the appearance of normal PDL space.[8] Normally the PDL has a width of around 0.15 mm to 0.21 mm, widening or changes in the PDL can be a sign of abnormalities in the condition of the teeth and their supporting structures.[12]

The reaction of occlusal forces is absorbed by PDL plays a role in reffering it to the surrounding bone, so the PDL destruction can result in various disorders including matrix connective loss, pathological tooth movement, bone resorption, malocclusion and TMJ disorders.[13] Accurate radiographic assessment is essential for diagnosing conditions like occlusal trauma, which may manifest as an alteration of PDL space, and for planning therapeutic interventions.

Recent advancements in imaging technologies, such as CBCT and digital radiography, have enhanced the accuracy and detail of radiographic evaluations. These technologies provide high-resolution images that can better delineate the fine structures of the periodontium, allowing for more precise measurements and assessments of the PDL under various occlusal conditions. This detailed imaging capability is crucial for both diagnosis and treatment planning, particularly in complex cases involving occlusal discrepancies and periodontal disease.[7,14–16] Radiographic imaging techniques are critical in assessing occlusal trauma and its impact on the PDL and surrounding structures. Conventional radiographs, CBCT, CT and micro-CT are commonly used modalities to visualize occlusal loads effect. Traditional periapical and panoramic radiographs provide a broad overview of the dental

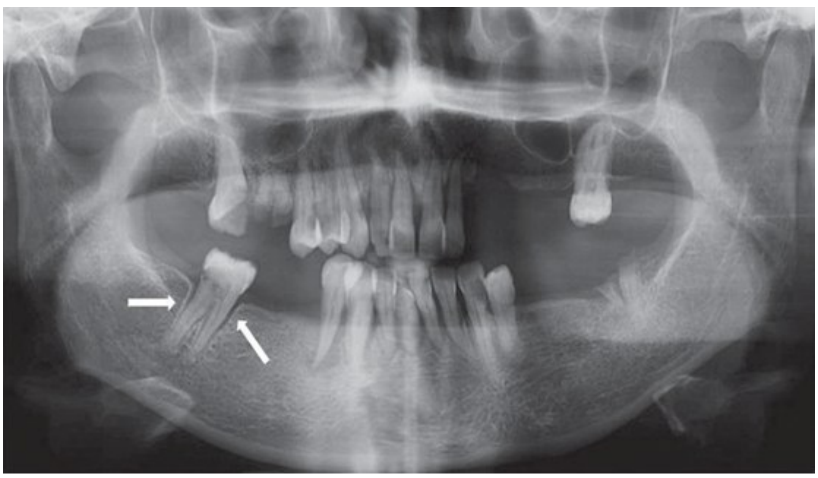

Figure 1. Panoramic radiograph shows periodontal ligament widening around the second molar mandibular right is evident with loss of neighboring teeth, subjecting it to heavy occlusal trauma[12]

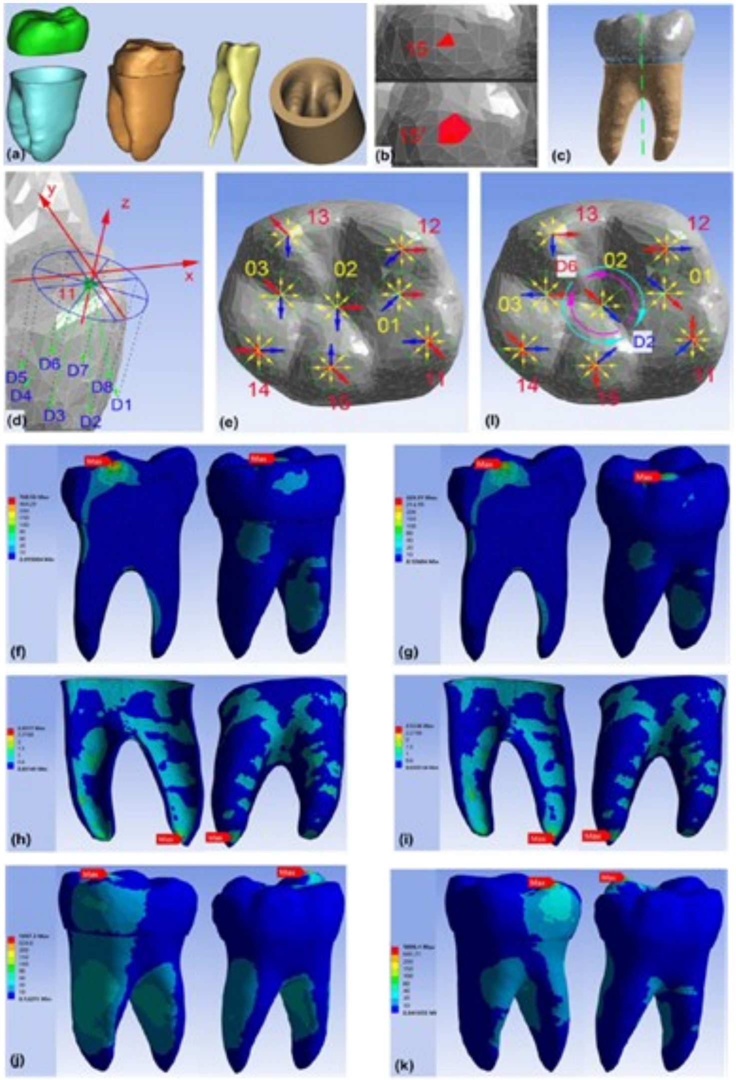

Figure 2. Finite element modeling of first molar mandibular right, with effects of area, location, and direction of loading. (a) Model of enamel (green), periodontal membrane (blue), dentin-cementum complex (brown), pulp (dark yellow), and alveolar bone (dark gray). (b) Loading using single and double triangular planes at site 15. (c) tooth long axis (d) eight loading directions map at site 11. (e) Eight loading map locations on occlusal surface, indicating directions of maximum (red arrows) and minimum (blue arrows) Maximum Periodontal Stress. Stress concentration from vertical loading at location 15 for single triangle planes (f) and (h), at five single triangle planes (g) and (i), Mesial-distal map at site 12 (j) and 13 (k). (l) Maximum Tooth Stress with direction of stress change[22]

and periodontal structures, they are helpful for identifying gross changes in the PDL space, alveolar bone resorption, and tooth mobility. However, the resolution is often insufficient for a detailed analysis of stress distribution.[7,17,18] CBCT offers three-dimensional imaging, providing detailed views of the dental and periodontal structures. It is particularly useful for evaluating the extent of bone loss and the integrity of the PDL. Studies have shown that CBCT can effectively detect changes in the PDL space due to occlusal trauma, offering a more precise assessment compared to conventional radiographs.[19,20]

Finite element analysis is a methode that can be used to analyze structural stresses, using a computer to solve large equations to calculate stresses based on the physical properties of the structure being analyzed. In-vivo studies are difficult in assessing biomechanical effects such as stress and strain, finite element analysis, is a valuable option for evaluating biomechanical factors. The stresses, strains, and deformations of structures with complicated geometry can be evaluated under deifferent loading and boundary sate using numerical methods, based on dividing a complex structure into elements, icluding tooth material heterogeneity and tooth contour irregularity in the model design and apply loads and magnitudes in different directions to complete analysis.[21] FEA using anatomical data obtained from various imaging modalities such as CBCT and CT with computational approach can help in visualizing the stress patterns and identifying areas of high stress concentration, and showing how the PDL responds to various occlusal forces, and understanding the biomechanical behavior of PDL under various loading scenarios.[13]

Research by Zhang et. al studying pattern of stress distribution using a FEM of the mandibular first molar based on a volunteer's CT image, by reconstructing the geometry of various components, as a digital representation of the teeth and their supporting structures, including the periodontal ligament using software (Mimics 10.1), by inserting a periodontal membrane between the root and the alveolar bone with 0.2 mm uniform thickness with the task of conducting simulations to determine the influence of the location, pattern, and mechanical loads direction on the teeth and periodontal Von Mises pressure. In this study, the

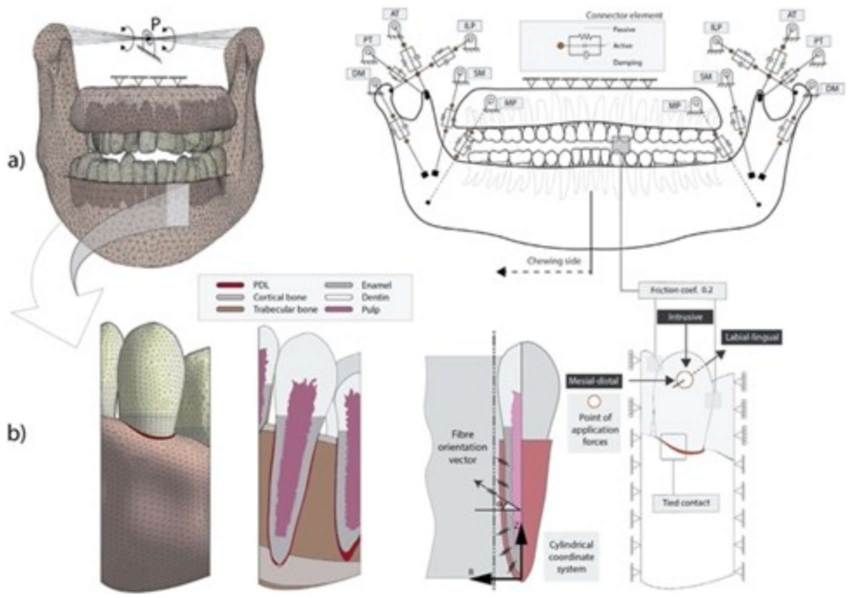

Figure 3. (a) Left: full dentition model mesh obtained by CBCT scan with mandible, maxilla, teeth, and PDLs. Right: schematic of boundary conditions applied to the model and the muscle system modelled. SM, superficial masseter; DM, deep masseter; ILP, inferior lateral pterygoid; AT, anterior temporalis; PT, posterior temporalis; MP, medial pterygoid. (b) Left to right: mesh of the portion of a human mandible obtained by µCT; section of the model with color-coded components; schematic showing of the cylindrical coordinate system used to describe the orientation of the fibres bundles, and boundary conditions applied to the model[13]

distribution and concentration of stress on the teeth and periodontal tissues under various occlusal load conditions were analyzed, it was seen that the pressure value on the periodontal ligament was generally much lower than that on the teeth under the same loading conditions, and it was seen that the size of the loading area affected the maximum periodontal pressure (MPS) value, where a larger loading area resulted in a smaller MPS value, indicating that the distribution of force in a larger area can reduce the pressure experienced by the periodontal ligament. The analysis also revealed that loading direction significantly affected the stress distribution in PDL.[22]

Micro-computed tomography (Micro-CT) has a relevant role in multi-disciplinary approaches, provides high-resolution, also three-dimensional images of of the internal structure of materials and biological tissues, suc as periodontal ligament. Micro-CT is an advanced imaging technique that generates X-rays that rotate around the sample, penetrate the sample, which is placed in the scanner, capturing multiple 2D images from different angles. As the X-rays penetrate the sample, they are attenuated to varying degrees depending on the density and composition of the material. A detector captures the transmitted X-rays, creating a series of 2D projection images that are processed using sophisticated algorithms to reconstruct a 3D representation of the internal structure of the sample. This reconstruction provides detailed information about the morphology, density, and microstructure of the sample. Micro-CT has high resolution, reaching resolutions of up to several micrometers, which can produce images of fine detail in biological tissues, such as the fibrous structure of the periodontal ligament (PDL).[13,23]

Micro-CT provides detailed anatomical and material property data, such as the microstructure of the PDL including its thickness, fiber orientation, and composition. These detailed structural data are essential for creating an accurate FEA model to analyze the damage mechanisms of the PDL under occlusal forces. The 3D reconstructions obtained from micro-CT scans serve as the basis for developing finite element models. This information is essential for determining material properties in FEA, to obtain a more realistic simulation, by integrating micro-CT data into FEA, effect of various occlusal forces and ditribussion on PDL can be performed. The FE model was scanned ex vivo using a micro-CT scanner, resulting in tomographic images that were rebuilt using computer software. It can display simulations that show stress distributions, potential failure points, and damage mechanisms, such as excessive fiber stretching or fluid pressure changes.[13,17] It can provide biomechanical insight, allowing for precise stress analysis that can lead to the determination of PDL mechanisms damage, which might be generated by mechanical loading and a hint of PDL in parafunctional and traumatic loading patterns. Micro-CT imaging can be one of modality for creating accurate FEA models to study the biomechanical behavior of the PDL under various occlusal loads.[13,17]

Study by Ortún-Terrazas et al. analyzed the PDL mechanical response and the destruction it endure when exposed to normal, parafunctional and traumatic occlusal forces considering the 3D loading, biological composition and PDL micromorphology. A 3D model of the human mandible containing canine teeth based on CBCT and micro CT images was created separately using finite element analysis (Figure 3). The first model

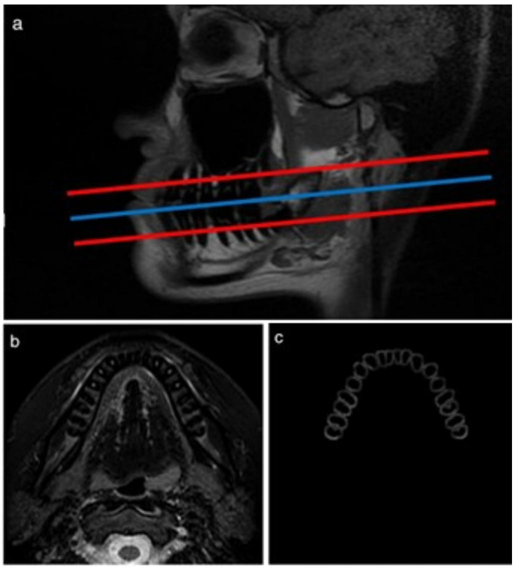

Figure 4 MRI image. (a) Positioning of imaging range by T1 weighted images. (b) Image of the mandible obtained by the IDEAL method. (c) Image obtained by extracting only the periodontal ligament equiv- alent based on the image in b[25]

was experimentally validated with occlusion analysis and exposed to muscle loading, where the calculated occlusal forces were then applied to a single tooth model to evaluate the collagen tissue damage and the extracellular matrix of the PDL. FE simulations produced similar occlusal patterns, with an initial contact on the left canine, driving the rotation of the tooth around its center of rotation due to the laterally applied occlusal forces. The collagen network damage and PDL extracellular matrix can occur under traumatic and frictional circumstances, mostly due to excessive fiber stretching and interstitial fluid pressure. The absorption of lateral occlusal forces is often caused by the initial contact of the canine tooth, the response of the PDL to occlusal forces is time-dependent and can be distinctively by cycles of occlusal forces and residual displacements of continuous state of tension. This study shows understanding biomechanical behaviour is important to determine the damage mechanisms caused by loading mechanism and PDL role in parafunctional and traumatic loading.[13]

Magnetic resonance imaging (MRI), although less commonly used in dental practice, offers excellent soft tissue contrast, making it a potential tool for assessing the PDL. Advances in MRI technology have improved its spatial resolution and 3D image capability, allowing for detailed visualization of the PDL and surrounding tissues without ionizing radiation.[24–26] In prognostic implications, understanding the radiographic appearance of occlusal loads and stress in the PDL is crucial for predicting the future prognosis of teeth. During clinical practice occlusal trauma evaluation is limited to clinical manifestations due to examination of articulating paper or fremitus. The presence of radiographic signs such as widened PDL spaces, angular bone loss, and hypercementosis can indicate a compromised periodontal environment, necessitating timely intervention.[14] Edema occurs in PDL of teeth that endure traumatic occlusion, the presence of the edema can responsively detect by MRI.[11,25]

Study of Dewake et. al evaluate association between clinical occlusal trauma score and the maximum signal intensity of the PDL observed on MRI. Higher clinical scores of occlusal trauma were associated with increased maximum signal intensity on MRI, indicating that MRI can effectively reflect the severity of occlusal trauma. MRI shows early occlusal trauma can be found even in obvious clinical manifestations absence. Early detection of these signs allows for implementing preventive measures, such as occlusal adjustments or splinting, to redistribute occlusal forces more evenly and reduce stress on the PDL. This suggests that MRI may be a valuable tool for early detection and treatment of occlusal trauma, potentially before significant clinical symptoms develop.[25] Radiographic evaluation is very important if clinical examination may not be enough to diagnose the suspected abnormal entity, furthermore radiographic monitoring can track the progression or resolution of periodontal conditions, providing valuable feedback on the effectiveness of therapeutic interventions.[27]

DISCUSSION

Occlusal loads, whether physiological or pathological, influence the stress distribution significantly within the periodontal ligament. Finite Element Analysis (FEA) has become an essential method for simulating and visualizing stress patterns in the PDL. It quantitatively calculates the stress and deformation within the periodontium using detailed anatomical models derived from micro-CT imaging, allowing for assessing the PDL's mechanical response under varying loading conditions.[6,13] The PDL plays a crucial role in transferring occlusal forces to the surrounding bone. Once occlusal loads are absorbed, they can lead to disorders ranging from mild to severe. Damage to the PDL can cause oral diseases, occlusal dysfunction, and even bone and tooth loss.[13]

Studies have demonstrated that occlusal loads can create stress concentrations in specific regions of the PDL, particularly in the apical areas of the root, during orthodontic tooth movement and other dental procedures. Under different loading conditions, stress distribution in the PDL can vary significantly, with higher stresses often observed in the cervical and apical regions.[4,28,29] Understanding this stress distribution is crucial for dental treatment planning, including orthodontic and restorative procedures. The PDL's ability to remodel and adapt to mechanical stimuli emphasizes the importance of controlling occlusal forces to prevent pathological conditions like occlusal trauma and periodontal damage.[4,28,30]

Clinical evaluation of occlusal trauma and PDL strength studied by Dewake et al. suggesting a potential new method for analyze occlusal trauma with MRI examination.[25] The magnitude and direction of occlusal loads greatly influence the stress distribution within the PDL. Vandana and Muneer investigated different occlusal forces on the PDL of a maxillary central incisor using FEA, showing that balanced occlusal schemes resulted in uniform stress distribution, and in contrast, unbalanced schemes caused localized stress concentrations, increasing the risk of periodontal damage.[1,18,31] Similarly, Chen et al. examined the effects of parafunctional occlusal loads, such as bruxism, on the PDL. Their FEA models revealed that excessive forces due to parafunctional activities significantly increased stress levels in the apical third of the PDL, potentially contributing to root resorption and other periodontal issues.[32] Pini et al. analyzed the impact of different loading conditions on stress distribution in the PDL of maxillary incisors, finding that lateral and oblique forces generated higher stress levels compared to axial forces, thus highlighting the PDL's vulnerability to non-axial loading.[33]

FEA models are often simplified by presume that occlusal forces act along the tooth's axis, with simplified PDL geometry and homogeneous behavior.[13] However, these models accuracy depends on the quality of the data input and assumptions about material properties and boundary conditions. Recent advancements in imaging technologies, such as micro-CT and MRI, have improved the accuracy of PDL models used in FEA.[11] Wang et al. used high-resolution micro-CT scans to create detailed FEA models of the PDL, enhancing the reliability of stress analyses. The integration of patient-specific data into FEA models represents a significant advancement, providing personalized insights into PDL biomechanical behavior.[31]

FEA has also been applied to evaluate the effects of periodontal treatments on stress distribution within the PDL. Murakami et al. studied the effect of splinting mobile teeth on PDL stress distribution, with their FEA model showing that splinting significantly reduced stress concentrations, demonstrating its potential benefit in periodontal therapy.[34] FEA has also been used to analyze the biomechanical implications of dental implants on adjacent teeth and periodontal structures. For example, Chen et al. assessed PDL stress distribution of teeth adjacent to implants, finding that implant placement can alter the stress distribution in neighboring teeth, which is crucial for implant planning.[32]

Recent studies have also utilized FEA to model the PDL and investigate stress distribution patterns under different occlusal loads. Patient-specific FEA models are now used to predict orthodontic treatment outcomes, offering a tailored approach to managing occlusal loads and minimizing periodontal risks.[35] Vukovic et al. applied FEA to analyze stress distribution in the PDL of a mandibular first molar under various loading scenarios, with their findings showing that oblique loads produced higher stress concentrations compared to vertical loads, suggesting tremendous potential for PDL damage under non-axial forces.[36] Lee and Kim incorporated the anisotropic and viscoelastic properties of the PDL into their FEA model and found that the highest stress concentrations occurred at the cervical margin, underscoring the importance of this area for periodontal health.[37] Research by Natali et al. further investigated the mechanical behavior of the PDL using an FEA model that accounted for its nonlinear, time-dependent properties. Their findings highlighted the role of the PDL's viscoelastic properties in dissipating stress under dynamic loading conditions.[38]

Nowadays evaluating methods to exam clinical occlusal trauma are mostly qualitative due to the complex pathophysiology and diverse clinical manifestations of occlusal trauma, making it challenging to integrate and evaluate them. Terrazas et al. used T-Scan III and FE simulations to visualize occlusal contact, showing similar results, which confirmed early contact on the left cuspid and lead the mandible slightly to the right.[13] These studies demonstrate that combining radiographic examinations with FEA can identify the PDL distribution patterns of occlusal loads. A recent case study involving a patient with severe bruxism demonstrated the utility of integrating radiographic imaging and Finite Element Analysis (FEA) in treatment planning.[39] The FEA model revealed significant stress concentrations in the apical third of the periodontal ligament (PDL), leading to early detection of potential root resorption. Based on these findings, the clinician was able to modify the occlusal load distribution through selective grinding and a custom occlusal splint, which successfully alleviated the excessive forces and prevented further periodontal damage. This case highlights the potential for FEA to enhance clinical decision-making, especially in cases where visual examination alone may be insufficient.[39]

FEA is a highly effective, non-invasive, and qualitative method for identifying regions of high stress contributing to soft tissue and bone degeneration in complex structures. The findings by Dewake et al. suggest that early occlusal trauma may be present even without visible clinical symptoms. Traumatic occlusion cannot be reliably detected through clinical examination alone; radiographic evidence is necessary to identify changes in the periodontal ligament. Integrating radiographic imaging with FEA makes early awareness and treatment of traumatic occlusal become possible. This method shows promise for the rapid assessment of both the morphological and physiological characteristics of the PDL space.[25]

Incorporating of 3D loading conditions from occlusal contact in future studies will aid in developing dental treatments and further promote the use of computational methods in medical practice.[19] The nature and magnitude of occlusal loads significantly influence stress distribution within the PDL. Moreover, radiographic monitoring provides valuable insight into periodontal health, allowing for the evaluation of treatment effectiveness and disease progression. Given the effectiveness of FEA in identifying high-stress areas within the PDL, it is recommended that clinicians incorporate FEA in the routine diagnostic workflow for patients exhibiting signs of occlusal trauma. This helps in early detection and prevention of occlusal trauma while providing precise data for treatment decisions. This approach can enable more precise treatment strategies, such as customized occlusal adjustments or splinting, to alleviate excessive stresses and prevent further periodontal damage. Additionally, integrating FEA with advanced imaging modalities like CBCT may enhance accuracy in identifying occlusal loads and stress distribution in the periodontal ligament, finding regions that risk for bone resorption, improving patient outcomes in both restorative and orthodontic treatments. Clinicians can identify high-stress areas and adjust treatment plans to optimize outcomes in periodontal and orthodontic care. Incorporating FEA into routine assessments may improve patient outcomes by enabling personalized treatment strategies.

Future research should focus on further validating FEA models through longitudinal clinical studies to assess their predictive accuracy in various occlusal load scenarios. Investigating the role of different occlusal forces, such as parafunctional habits like bruxism, in diverse patient populations could also provide deeper insights into the relationship between stress distribution and long-term periodontal health.

CONCLUSION

Advanced radiographic imaging modalities integrated with finite element analysis (FEA) can evaluate the distribution of occlusal force loading and show how stress processes are transmitted within the periodontal ligament (PDL). This shows that radiography play significan role in improving the understanding of periodontal biomechanical behavior, providing important insights into the mechanical response of the PDL to varying occlusal loads, and can be very useful in periodontal and orthodontic treatment.

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FOOTNOTES

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REVIEW ARTICLE

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Cone-Beam CT, CT and MRI for odontogenic tumors: a narrative review of imaging characteristics

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ABSTRACT

Objectives: This review article aims to examine the role of cone-beam computed tomography (CBCT) in the diagnosis and management of odontogenic tumors. Additionally, it evaluates CBCT's efficacy in the assessment of both benign and malignant odontogenic tumors, including ameloblastoma, odontoma, and odontogenic myxoma.

Review: This narrative review provides an in-depth analysis of CBCT imaging characteristics in the most common odontogenic tumors. The review highlights key CBCT features such as localization, peripheral structure, and internal architecture, emphasizing their impact on surrounding tissues. It compares the utility of CBCT with that of CT and MRI for the diagnosis of common odontogenic tumors, focusing on the strengths and weaknesses of each modality. The research questions addressed in this review include how CBCT can enhance diagnostic accuracy, what imaging characteristics are critical for differentiation between benign and malignant tumors, and how CBCT compares with traditional imaging methods in the context of maxillofacial tumor diagnostics.

Conclusion: CBCT's three-dimensional imaging capabilities provide clinicians with enhanced visualization of odontogenic tumor characteristics, aiding in accurate lesion localization, differentiation of tumor types, and treatment planning. CBCT is particularly useful for assessing the internal structure and peripheral boundaries of odontogenic tumors, improving the ability to distinguish between benign and malignant lesions. However, its limitations in soft tissue resolution underscore the continued importance of CT and MRI in comprehensive maxillofacial imaging.

Keywords: *Ameloblastoma, odontogenic tumors, benign lesions, CBCT 3D, maxillofacial imaging*

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INTRODUCTION

Maxillofacial imaging has seen significant advancements over the past decades, with cone-beam computed tomography (CBCT) emerging as a pivotal diagnostic tool following the widespread use of panoramic radiography. Initially developed in the early 1980s for angiography, CBCT found its way into dentistry by the early 1990s and has since become indispensable in evaluating dentoalveolar structures.[1,2] By utilizing a cone- or pyramid-shaped ionizing radiation source and a rotating gantry attached to a two-dimensional detector, CBCT produces volumetric images with high resolution and isotropic voxel size.[3]

This review aims to explore the role of CBCT in diagnosing odontogenic tumors, its strengths and limitations, and its comparison with medical CT and magnetic resonance imaging (MRI). Additionally, the most common odontogenic tumors and their specific imaging characteristics are discussed to enhance the understanding and diagnostic accuracy of clinicians.

REVIEW

This review was conducted by analyzing literature related to CBCT findings in odontogenic tumors. Articles published between 1990 and 2023 were reviewed from databases such as PubMed, Scopus, and Web of Science. The search terms used included *"cone-beam computed tomography"*, *"odontogenic tumors"*, *"ameloblastoma"*, *"odontoma"*, *"odontogenic myxoma"*, and *"malignant odontogenic tumors"* to include the most common odontogenic tumors' imaging characteristics in this study. Inclusion criteria were English-language studies that discussed the imaging features of odontogenic tumors with a specific focus on CBCT findings. Exclusion criteria included studies focused solely on non-odontogenic lesions and those without CBCT imaging results.

ODONTOGENIC TUMORS

Odontogenic tumors are a diverse group of neoplasms that originate from the tissues involved in tooth development, including the enamel, dentin, cementum, and their associated structures.[4] These tumors vary widely in their biological

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behavior, ranging from benign, slow-growing lesions to aggressive, malignant tumors capable of local invasion and distant metastasis.[5,6] Although they are relatively rare, odontogenic tumors are of significant clinical importance due to their potential impact on the jaws and surrounding tissues.[6] Accurate diagnosis and proper management are crucial, as some odontogenic tumors may mimic other maxillofacial pathologies. Imaging modalities, particularly CBCT, play a vital role in identifying and characterizing odontogenic tumors, offering detailed insights into their localization, internal architecture, and effects on adjacent structures.[7, 8] Understanding the imaging features of odontogenic tumors is essential for clinicians to differentiate between benign and malignant forms, ensure appropriate treatment planning, and prevent unnecessary interventions.

AMELOBLASTOMA

Ameloblastomas are the most common odontogenic tumors, accounting for approximately 80% of cases in the posterior mandible.[9-10] CBCT plays a crucial role in their evaluation, as it offers superior spatial resolution and detailed imaging of both the tumor and surrounding structures. Ameloblastomas are most commonly found in the posterior mandible and typically present with well-defined, corticated borders.[11] CBCT imaging reveals that ameloblastomas may appear as either multilocular, exhibiting a honeycomb or soap bubble appearance, or as unilocular radiolucent lesions (Figure 1). The septa within the tumor are often thick and curved, representing residual bone without reactive bone formation (Figure 2). Ameloblastomas exert significant pressure on surrounding structures, leading to cortical bone expansion, destruction, and even perforation. Additionally, root resorption and tooth displacement are frequently observed.[11-13]

On CT, ameloblastomas typically present with well-defined borders and low internal attenuation. The locularity of these tumors varies, with some showing a honeycomb-like appearance and others appearing unilocular.[14] All cases exhibit bone expansion, primarily on the labial side. MRI findings demonstrate well-defined borders with solid, moderately low signal intensities and small cystic high-signal intensities on T2-weighted images, while intermediate signal intensities are noted on T1-weighted images. Linear low signal intensity on both T1- and T2-weighted images was observed in several cases. Gadolinium-enhanced MRI revealed moderate enhancement in all cases, with dynamic-enhanced MRI showing persistent enhancement, suggesting solid components within the lesion.[15,16] These findings help differentiate ameloblastomas from other cystic lesions in the maxillomandibular region, such as odontogenic keratocysts, especially due to the high recurrence rates of both. MRI is particularly valuable for detecting the mixed solid and cystic patterns, thickened walls, and strong

Figure 1. (A) Sagittal CBCT section illustrating the characteristic "soap bubble" appearance. (B) Sagittal and (C) axial sections of the same ameloblastoma demonstrating the multilocular structure. Arrows highlight the multilocular features.

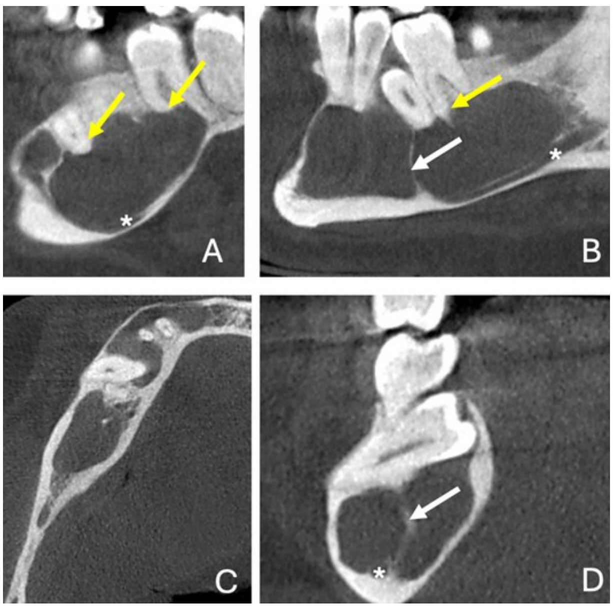

Figure 2. (A, B) Sagittal CBCT images and (C, D) axial CBCT images depicting the septa formation characteristic of ameloblastoma. Yellow arrows indicate root resorption, while white arrows point to the septa formation. The asterisk marks the inferior displacement of the mandibular canal

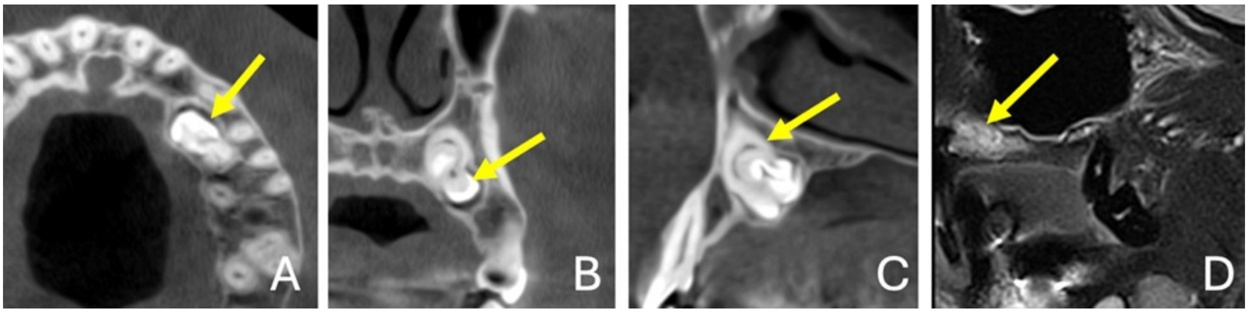

Figure 3. (A, B, C) Axial, coronal, and sagittal CBCT sections of an odontoma, highlighting its mixed radiographic appearance and well-defined peripheral borders. (D) Sagittal section of a Spin Echo Magnetic Resonance Image of the odontoma, displaying both hyperintense and hypointense structures. Arrows denote the complex odontoma

enhancement of solid components, which are characteristic of ameloblastomas.[15]

ODONTOMA

Odontomas are benign odontogenic tumors composed of fully differentiated dental tissues such as enamel, dentin, cementum, and pulp.[17] They are often considered hamartomas rather than true neoplasms due to their limited growth potential. Odontomas are most frequently found in the maxilla.[18] On CBCT, they appear as well-defined, hyperdense lesions with a density similar to dental tissues. These tumors are often associated with unerupted teeth, and CBCT imaging is particularly useful in determining the extent of tooth impaction and buccolingual inclination.[19] There are two types of odontomas: Complex odontomas, which present as amorphous masses with varying densities and are typically surrounded by a hypodense border, and compound odontomas, which consist of multiple tooth-like structures of varying density and are characterized by a hypodense margin (Figure 3).[20-22]

ODONTOGENIC MYXOMA

Odontogenic myxomas are benign tumors that arise exclusively from the facial skeleton, particularly the posterior mandible.[23,24] CBCT is valuable in identifying these lesions due to their subtle radiographic presentation and varied internal structure.[25-27] The peripheral boundaries of these tumors may present as either corticated or diffuse, with scalloping observed in some cases. Internally, odontogenic myxomas are typically multilocular, often displaying a honeycomb or soap bubble appearance.[24-26] The septa within the tumor are usually straight and thin, which helps differentiate them from ameloblastomas, where the septa tend to be more curved. Tooth displacement is a common effect on surrounding structures, although root resorption is rare. In some instances, cortical expansion may occur, though it is generally less pronounced than in ameloblastomas.[25-27]

Radiological findings, such as the presence of tooth resorption, septa formation, and perforation, were not found to be associated with recurrence.[24] In multilocular lesions, the frequency of expansion and perforation was higher compared to unilocular lesions. The recurrence rate may vary depending on the treatment methods used. Tooth mobility is rarely observed, and paresthesia may occur in some cases.[29]

MRI findings of odontogenic myxoma often help distinguish it from ameloblastomas, although the two can appear similar on conventional radiographs. On MRI, odontogenic myxomas commonly show intermediate signal intensity on T1 -weighted images (T1WI) and homogeneous high signal intensity on T2-weighted images (T2WI).[30] Dynamic MRI has been shown to differentiate these lesions effectively. In ameloblastomas, the solid areas typically exhibit rapid enhancement, reaching peak contrast between 45-60 seconds, followed by either sustained enhancement or gradual wash-out over the next 600 seconds. In contrast, the cystic areas of ameloblastomas show no enhancement. Odontogenic myxomas, on the other hand, show a gradual increase in enhancement across the whole tumor area, including the central portions, with a peak at 500-600 seconds. This gradual enhancement pattern seen in myxomas, even in areas not initially enhanced on Gd-T1 weighted images, is minimal but distinctive. Post-contrast MRI (Gd-T1WI) reveals peripheral rim enhancement, corresponding to the fibrous capsule seen histopathologically. The central portion of the myxoma, which shows no enhancement on Gd-T1WI, consists of poorly differentiated cellular mucoid matrix. Therefore, dynamic MRI, with its ability to capture these differences in enhancement patterns, is a useful diagnostic tool for differentiating odontogenic myxomas from ameloblastomas.[31,32]

MALIGNANT AMELOBLASTOMA

Malignant ameloblastoma is known for its potential to recur even after many years, often complicating long-term management.[33-35] Despite being histologically benign, its biological behavior includes aggressive local invasion and a high recurrence rate, especially in cases where the tumor is not entirely excised.[34,35] Malignant ameloblastomas can metastasize to distant sites, with the lungs being the most frequent target, as observed in several reported cases.[33-41] For example, a case report highlighted a patient developing pulmonary metastases 45 years after the initial diagnosis, emphasizing the indolent yet persistent nature of this tumor.[38]

Given the potential for late recurrence and metastasis, imaging plays a crucial role in both the initial diagnosis and follow-up of malignant ameloblastomas. CBCT plays a key role in detecting metastasis and local recurrence. Malignant ameloblastomas primarily affect the mandible, particularly in the premolar and molar regions. On CBCT, these tumors exhibit variable imaging patterns, ranging from well-corticated borders to ill-defined margins with evidence of soft tissue invasion. Internally, malignant ameloblastomas can present as unilocular or multilocular lesions, often displaying a honeycomb or soap bubble appearance. Additionally, CBCT frequently reveals cortical bone destruction and invasion into adjacent tissues, underscoring the aggressive nature of these tumors.[34-38] PET-CT, in particular, has proven to be a valuable tool in detecting recurrent or metastatic disease.[34] PET-CT combines metabolic imaging with anatomical detail, enabling clinicians to assess both the primary tumor and distant metastases. FDG-PET imaging has shown promise in detecting metabolically active regions of ameloblastomas, particularly in distinguishing malignant transformations from benign recurrences.[34]

DISCUSSION

Odontogenic tumors, particularly ameloblastomas and odontogenic myxomas, present significant diagnostic challenges due to their diverse presentations, growth patterns, and potential for recurrence.[4,7-9] The utility of CBCT and other imaging modalities such as CT and MRI in the evaluation of these tumors cannot be overstated. These imaging technologies are critical for assessing tumor characteristics, guiding treatment decisions, and predicting potential outcomes, including recurrence and metastasis.[11,14,34,35] CBCT's ability to provide three-dimensional, high-resolution images of bone structures makes it indispensable for assessing odontogenic tumors.[6] CBCT excels in visualizing bony details, making it especially useful in cases where tumors infiltrate the mandible or maxilla.[7,8] Ameloblastomas, which most commonly affect the posterior mandible, are often multilocular, displaying a honeycomb or soap bubble appearance on CBCT scans . This imaging modality offers excellent spatial resolution, allowing clinicians to assess not only the tumor's internal structure but also its impact on surrounding bone, such as cortical expansion or destruction. Similarly, odontogenic myxomas exhibit multilocular radiolucencies on CBCT, often with thin septa.[12-14]

CBCT's relatively low radiation dose compared to medical CT and its capacity to provide isotropic voxel data have contributed to its widespread use in dental and maxillofacial radiology.[2,3] However, CBCT's primary limitation lies in its inability to provide detailed soft tissue contrast.[3] This makes it less effective for evaluating soft tissue involvement or detecting malignant transformation, necessitating the use of complementary imaging modalities such as MRI and FDG-PET.[16,34,35] CT scans are particularly useful for detecting cortical bone destruction and soft tissue invasion, especially in cases of malignant ameloblastomas. Malignant ameloblastomas often present with ill-defined margins on CT, indicating aggressive infiltration of surrounding tissues. This capability is critical in treatment planning, particularly for surgical excision. Additionally, contrast-enhanced CT can help to differentiate cystic from solid components within the tumor, which is important for accurate diagnosis.[42,43] The use of contrast helps to distinguish cystic lesions from solid or vascular structures, as the cystic areas typically appear as non-enhancing or minimally enhancing compared to solid tissue, which absorbs the contrast medium.[42,43]

MRI plays a complementary role by providing superior soft tissue contrast, making it indispensable for evaluating tumors with complex internal structures or those that invade soft tissues. Dynamic MRI has been shown to effectively differentiate between ameloblastomas and odontogenic myxomas based on their enhancement patterns. In ameloblastomas, the solid areas typically demonstrate rapid enhancement with contrast, followed by a gradual washout, whereas cystic areas show no enhancement. In contrast, odontogenic myxomas exhibit gradual enhancement across the entire lesion, including regions that may appear unenhanced on initial scans. This difference in enhancement patterns is crucial for distinguishing these two entities, which can appear radiographically similar on conventional imaging.[30-32]

One of the most concerning aspects of treating odontogenic tumors, particularly ameloblastomas, is their high recurrence rate.[34-41] Even after seemingly successful resection, ameloblastomas can recur many years later, as demonstrated by case reports describing recurrences up to 45 years after initial treatment.[38] This prolonged risk of recurrence underscores the need for long-term imaging surveillance, which should include regular CBCT scans to assess for bony changes and FDG-PET/CT or MRI for detecting soft tissue or metastatic involvement.

The comparative utility of CBCT, CT, MRI, and PET/CT in diagnosing and monitoring odontogenic tumors depends on the specific clinical scenario. CBCT is ideal for initial assessments of bony involvement and for monitoring post-surgical bony healing. However, when soft tissue involvement or malignant transformation is suspected, MRI and FDG-PET/CT provide the necessary additional information. CT remains a valuable tool for assessing cortical bone integrity and detecting subtle changes that may indicate aggressive tumor behavior.

CONCLUSION

This review has highlighted the strengths and limitations of CBCT, medical CT and MRI, for assessing common benign and malignant odontogenic tumors such as ameloblastomas, odontomas, and odontogenic myxomas. CBCT's ability to provide visualization of tumor localization, peripheral boundaries, internal structures, and effects on surrounding tissues makes it a valuable asset.

While CBCT excels in hard tissue assessment, complementary imaging modalities like MRI and PET-CT are crucial for evaluating soft tissue involvement and detecting tumor recurrence or metastasis. In particular, PET-CT has proven to be highly effective in identifying recurrent or metastatic malignant ameloblastomas, which have the potential to recur even decades after initial treatment. Dynamic MRI also aids in distinguishing between odontogenic tumors, particularly in differentiating odontogenic myxomas from ameloblastomas based on enhancement patterns.

Utilizing CBCT, MRI, and PET-CT is essential for comprehensive evaluation. CBCT remains a cornerstone in oral and maxillofacial diagnostics, while advanced imaging modalities contribute to broader evaluation of the odontogenic tumors.

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FOOTNOTES

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