The Importance of Cone-Beam Computed Tomography in Clinical Research: Gender Differences and Bilateral Symmetry of Permanent Teeth Anatomy in a Saudi Arabian Population

By

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ABSTRACT

Aims and Objectives: To retrospectively explore the relationship of maxillary and mandibular permanent dentition taking into consideration the number of roots, their respective quantity of root canals, the bilateral symmetry of root canal morphology and root canal configurations between both genders, in a Saudi Arabian population.

Materials and Methods: This study comprised of 208 subjects (48% males and 52% females) with a mean age of 28.74±9.56 years. The CBCT images of the recruited subjects were evaluated for all permanent teeth except third molars. A careful examination was obtained by optimal visualization using all software features to investigate the differences between both genders and to evaluate the bilateral symmetry of number of roots, number of canals and root canal system configurations. The data was analyzed using SPSS 25. Cohen's Kappa test was used for reliability and bilateral symmetry, while, Chi-squared test was used for the differences

between both genders in relation to the study variables. A P-value < 0.05 was considered significant.

Results:

Gender differences: A total of 5254 maxillary and mandibular permanent teeth were evaluated. In relation to the number of roots, there were no significant differences between the genders for maxillary and mandibular teeth (P= 0.064) as well as for maxillary and mandibular teeth separately (P= 0.315 and P= 0.100, respectively). Significant difference was found between males and females in relation to number of canals of maxillary teeth (P= 0.014). For mandibular teeth, the significant level of difference was at the cut-off point (P= 0.050). For both arches the distribution among both genders was not significant (P= 0.082). Conversely, the difference between both genders with regard to canal configuration of maxillary roots was highly statistically significant (P< 0.001). For mandibular teeth, difference between males and females in relation to canal configuration of anterior and premolar teeth was significant (P= 0.016) while, the same was not significant when related mesial roots of 1st and 2nd molars (P= 0.205). However, a greater significance was found when distal roots of 1st and 2nd molars were compared (P< 0.001).

Bilateral symmetry:

The Bilateral symmetry of number of roots was 100% in maxillary centrals, laterals, canines, 1st molars, and 2nd molars. In the mandibular arch however, it was 100% in mandibular centrals, and 2nd premolars only. The most frequent asymmetry was exhibited by the maxillary 1st premolars (14.9%). In relation to number of canals, the bilateral symmetry was 100% in maxillary centrals and laterals only. The commonest asymmetry was found in maxillary 2nd molars (18.9%). When canal configuration was assessed, the bilateral symmetry was found to be 100% in maxillary centrals and laterals. However, the most frequent asymmetry was found in maxillary 2nd premolars (32.2%).

Conclusion:

No significant differences were found between both genders in relation to the number of roots. Regarding number of canals, significant differences were detected only in 3 out of 14 groups of teeth. Overall, females had lower number of canals than males. Canal configuration was also governed by gender in this study. Bilateral symmetry was more evident when number of roots were assessed than the canal configurations

Clinical relevance: The influence of gender should be considered when root canal morphology is assessed and henceforth root canal treatment is to be performed. Clinicians should be aware of these variations particularly when treating contralateral teeth in the same individual as well. Also, the utilization of CBCT could aid in proper dental therapy for teeth when conventional 2-D radiographs are inconclusive.

Keywords: CBCT, Root Anatomy, Saudi population, Gender differences, Bilateral symmetry

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I. GENERAL INTRODUCTION

I.1 Endodontic objectives:

Endodontics is a branch of dentistry specialized in the morphology, physiology, and pathology of the human dental pulp and periapical tissues. It includes science and practices within these areas and is currently termed as root canal therapy or pathodontia. About a century ago, Dr. Harry B. Johnston came up with the term “Endodontics” from the Greek word: “en” meaning in or within, "odous" meaning tooth: “The process of working within the tooth” So, endodontics recently is solidified to focus on two areas:

1. Morphology, physiology, and pathology of the human dental pulp and periapical tissues
2. Etiology, diagnosis, prevention, and treatment of disease of the pulp and associated periapical conditions. (1)

Scientific and clinical opinions about endodontics vary widely worldwide, however, they all agree in one basic statement; that cleaning and shaping of the canal is the most important aspect of endodontic therapy. (2–7) Disinfecting the root canal system (RCS) with irrigation in combination with root canal debridement is considered one of the most important factors in the prevention and treatment of endodontic pathoses. (8) The rationale of endodontics is based on simple biologic principles. Significant reduction or complete elimination of microorganisms and infected necrotic pulp tissue are critical factors for success. (9)

Practically, this procedure is not simple, since the pulp tissue is enclosed inside a hard tissue ‘dentin” in a RCS. The defense mechanism inside the RCS it not fully equipped by the body’s immune system because of the special nature of teeth and lack of bilateral circulation in the pulp tissue. Hence due to this and various other factors, most of which are bacterial in nature, the pulp tissue can go into vascular necrosis and/or infectious necrosis. Consequently, irritants and bacterial byproducts escape the root exit to cause lesions known as Lesions from Endodontic Origin (LEO). Root canal treatment (RCT) then is indicated and basically diseased teeth and peri-radicular tissue can be managed if diagnosed properly. (2,3)

Successful RCT after proper diagnosis and treatment planning is based on applying knowledge of tooth anatomy, root morphology and performing adequate chemo-mechanical cleaning, shaping and filling of the RCS three dimensionally. (10) Throughout the years, many instruments and techniques were used for mechanical cleaning and shaping to address the complexity of anatomical variations of the RCS. The real challenge is dealing with the reality that a root canal system is a three dimensional object which include fins, isthmuses, lateral canals and other complex structures that need to be cleaned and filled. Therefore, clinicians should be aware of the complexities of the "pulp space" rather than thinking about the RCS as a straight canal from orifice to apex.(2,3) It is well known that after performing an adequate cleaning, shaping and establishing a coronal seal endodontic treatment yields great success.(11) Subsequently, it is henceforth appropriate to summarize the main principles of cleaning and shaping the RCS when performing RCTs:

Principles of Cleaning and Shaping:

Tooth anatomy and morphology, the endodontic instruments and irrigation solution play a crucial role in cleaning the RCS. Even with contemporary instrumentation, complex RCS including lateral and accessory canals, canal curvatures, canal wall irregularities, fins, and isthmuses make total debridement virtually impossible. Since the current methods are not able to touch and debride all aspects of RCS, reducing the amount of irritants to a significant number within the RCS is therefore the main goal of cleaning. (12)

The overall goals of successful RCT are to facilitate cleaning and provide space for obturation. It is imperative to shape the canal accordingly if the latter is to be achieved. The main objectives of shaping are to maintain or develop a continuously tapering funnel from the canal orifice to the apex which allows for the achievement of general goals of thorough treatment. (13) Schilder *et al.* established certain constant principles for this, however, RCS are varied among different teeth and each one should be considered individually.(2) The principles are as follows:

1. Root canal preparation should develop a continuously tapering funnel from the root apex to the coronal access cavity.
2. The cross-sectional diameter of the preparation should be narrower at every point apically and wider at each point as the access cavity is approached.
3. The preparation should occupy as many planes as are presented by the root and the canal.
4. The preparation should flow with the shape of the original canal.
5. The apical foramen should remain in its original spatial relationship both to the bone and to the root surface.
6. The apical opening should be kept as small as is practical in all cases.

The knowledge of common root canal morphology and its frequent variations is a basic requirement for success during root canal procedures.

I.2 Root Canal Anatomy and Classification Systems:

RCS can take numerous configurations and presents many shapes. A thorough knowledge of human teeth morphology, proper understanding and interpretation of dental x-rays, and various other similarly fundamental endodontic procedures are essential for successful RCT. With the presence of a complex anatomy, utilizing magnification and illumination is a huge aid to manage such cases. (14)

Peters et al. (15) in a Micro-Computed Tomography (μCT) study demonstrated that, the geometry of the untreated root canals had more influence on the final changes produced by instrumentation techniques, hence, even after instrumentation about 35-40% of the RCS was not treated properly. This finding stresses the significance of the canal morphology. It is well established that a root with a tapering canal and a single foremen is the exception rather than the rule since the earliest relevant works on this by Preiswerk in 1912, Fasoli and Arlotta in 1913, plus Hess and Zurcher in 1917, to more recent studies. (19–22)

A number of studies have shown wide a variety of internal morphology of the RCT including: c-shaped canals, loops, accessory canals, fins, deltas and etc. So, clinicians should be aware of these variations and treat every single tooth as having a complexly unique anatomy keeping in mind that the RCS may branch, divide and rejoin again. (16–23) Because the great number of variations in the root canal anatomy, investigators came up with classification systems to ease the process of identification, understanding and communication in the dental community. Weine F.S. *et al.* (24), was the first to classify root canal configurations into four types:

- Type I (1-1): Single canal runs from orifice to apex,
- Type II (2-1): Two canals unite into one at apex,

- Type III (2-2): Two canals from orifice to apex with no connection, and
- Type IV (1-2): One canal divides into two.

Vertucci et al. (25) in his study found a much more complex canal system and categorized them into eight configurations. (Figure 1) His classification is the most famous and widely used in endodontics, and it is as follows:

- Type I (1-1): Single canal runs from orifice to apex.
- Type II (2-1): Two canals arise from pulp chamber which unite in its course into one. Type III (1-2-1): One canal arises from pulp chamber and during its course splits into two. These two canals again unite into one before exiting from apex.
- Type IV (2-2): Two canals run separately from orifice to apex.
- Type V (1-2): One canal arises from floor of pulp chamber and during its course divides into two.
- Type VI (2-1-2): Two canals start from pulp chamber, during its course; they unite into one and then again divide into two before exiting from root apex.
- Type VII (1-2-1-2): One canal leaves the pulp chamber which divides and again unites into each other in due course and finally divide into two before exiting from apex.
- Type VIII (3-3): Three canals leave the pulp chamber and run independently towards the apex.

Caliskan et al. (19) reported similar canals system configurations in a Turkish population compared to Vertucci, however, there are some variations that could be related to variations in ethnicity. Kartal and Yanikoglu (21) found two new canal configurations in mandibular anterior teeth which are not mentioned previously. Also, Gulabivala et al. (20) in a Burmese population reported seven additional canal configurations in mandibular first molars. Sert and Bayirli (22) studied root canal configurations in a large number of teeth (2800) in a Turkish population. 99% of their results were in agreement with the Vertucci classification, while, the remaining 1% (36 teeth) represented 14 additional canals configurations. Some teeth with unusual anatomies had their own classification, for example maxillary molars with four roots, maxillary premolars with three canals, the middle mesial canal, and distolingual root in mandibular molars. (33) Also, Kottoor et al. (34) and Albuquerque et al. (35) suggested a new system to classify RCS in maxillary and mandibular molars, respectively. In addition to *in vitro* studies, many case reports have reported a variety of complex canal configurations. (36) Other studies in different races and populations have reported wide varieties and differences in canal anatomy as well. (37–41) Contemporary literature reveals inconsistencies with the older one regarding the classification of the RCS of several tooth types. Advances in 3-D imaging technology has confirmed this variations and shown more complex anatomy and many canal configurations which did not fit in any presently utilized classification. (42–45) So, based on results from old and recent anatomical studies using µCT technology, a highly complex RCS is evident, and a new simple classification system is needed.(46) Most recently, a new canal configuration system has been proposed by Ahmed *et al.*(47) This classification aims to provide a simple, accurate and practical system that allows students, dental practitioners and researchers to classify root and root canal configurations. It is basically naming the tooth number, number of roots and root canal configuration types as one figure, without going in many details and abnormalities for the ease of the process.

I.3 Methods Used to Study Root Canal Anatomy:

During the past few decades, many techniques have been developed to evaluate external and internal anatomy of the teeth that include plastic resin injections, radiography, histology, Scanning Electron Microscopy (SEM), clearing of samples with ink injection, conventional Computed Tomography and μCT.(48,49) All these methodological approaches provided useful information to clinicians, however, inherent limitations of these techniques have encouraged the search for newer methodologies that could potentially help to read the anatomy in vivo. Recently, Cone Beam Computed Tomography (CBCT) has been widely used as an improvement of the diagnostic tools by the practitioners. CBCT now provides the clinician with the ability to observe an area in three different planes and thus to acquire three-dimensional (3-D) information and many studies have reported the usefulness of *in vivo* CBCT analysis in determining root canal anatomy. (50–53) So, with the help of 3-D technology, root morphology can be visualized in 3-D including the number of root canals, allowing a thorough understanding of the true morphology of the RCS. (54)

The need to understand dental anatomy in 3-D is not limited to non-surgical RCT, it is also effective for endodontic surgery which require a thorough knowledge of tooth anatomy and root canal morphology so that microorganisms and pulp tissue can be accessed, removed and root ends be managed properly. (55) With the availability of CBCT as a clinical methodology to diagnose and interpret the RCS properly, dentist are able to identify many more irregular and challenging root canal anatomies before initiating the RCT.(56,57) CBCT as a 3-D technology proved its ability to show comparable details to old methodologies: such as canal staining and clearing techniques for identification of the root canal morphology. (58)

I.4 3D Cone-Beam Computed Tomography:

The first 3-D technology to study tooth morphology was conventional medical tomography, and it failed because of the poor resolution.(59) More recently, µCT became popular in dental research because of its high resolution, which allows a precise 3-D reconstruction to evaluate external and internal root anatomy.(60,61) Followed by more studies using the same technology with different applications and methodologies to evaluate root canal morphology *in vitro*. (15,56,62–67) Despite the high anatomical details µCT provides, so far, these techniques are time consuming and not applicable in the dental office. It remains a research tool and cannot be used for human imaging *in vivo*. More recently, CBCT machines have become affordable and available for dental offices, which offer immediate high diagnostic details. (68,69) CBCT is the only *in vivo* method which is capable of providing high quality anatomical details in a 3-D manner compared to the µCT.

CBCT can be simply defined as an extra-oral 3-D imaging system dedicated to explore dento-maxillo-facial structures. (70) This modality uses a cone beam shaped acquisition of images of the entire volume as it rotates around the anatomy of interest. CBCT offers high-resolution, isotropic images that allow effective evaluation of root morphology and detection of any fine abruptions in the RCS. The resolution of conventional 2-D radiographs (18 microns) is superior to CBCT, however, the availability of 3-D information is paramount in characterization of RCS. 2-D grayscale images, whether conventional film based or digital, are poor representations of the pulpal anatomy, they underestimate canal structure greatly and often cannot accurately visualize periapical changes. In contrast, CBCT helps the clinician to view the tooth and pulpal structures in thin slices in all three anatomic planes: axial, sagittal, and coronal. (71) CBCT scans provide the practitioners with many advantages: such as the ability to change the vertical or horizontal angulation of the image in real time and 3-D surface rendering. Also, it provides thin-slices of the object, grayscale data of varying thicknesses and with the help of a dedicated software, images can be studied in multi-planar reformation which help to get a high details in a 3-D manner for better diagnosis. Another important feature of CBCT is no structural superimposition, so any object can be evaluated clearly. (72–77)

Currently, there are over 40 CBCT scanners on the market. Researchers and practitioners should be aware that, the results of research on a specific CBCT scanner may not be applicable to another one. That because every machine is different with regard to their specifications, exposure settings, effective dosages and image quality. The principles of radiation protection must be adhered to IRMER 2000, Holroyd & Gulson 2009 and Patel & Horner 2009.(78–80) As with any ionizing radiation imaging device, the radiation dose must be kept 'as low as reasonably achievable'. (ICRP 2007) When the benefits overweigh the risk for the sake of patient's good and after getting approval from the subject, a CBCT scan may be taken.(81) The radiation exposure dose from CBCT is 10 times less than that of conventional CT scans during maxillofacial exposure (68μSv compared to 600μSv of conventional CT), with great dimensional accuracy.(82) More recent CBCT machines have reduced exposure time and lowered radiation doses compared to conventional CT. In addition, the field of view can be as small as 4x4cm, but still have very good spatial resolution in all three planes. (83–86) CBCT has high accuracy and sensitivity and can capture the maxilla and mandible in a single rotation of the X-ray source.(84,87,88) CBCT helps in researching and understanding the root canal morphology. It also helps the clinician identify all canals in a given tooth and even to project the smallest access cavity possible prior to endodontic treatment. (89)

CBCT is capable of providing sub-millimeter resolution (2 \line pair/mm) images of higher diagnostic quality, with shorter scanning times (~60s). Increasing availability of CBCT machines in dental offices will provide clinicians with immediate 3-D representation of the maxillofacial structures with minimal distortion and reduced radiation hazards. A high correlation was found between histological sections and CBCT images, which makes CBCT viable for anatomical studies.

I.5 Root Canal Anatomy Differences Between Genders:

Differences between genders regarding anatomical variations and incidence of some disease is well documented in medicine.(90,91,92) In dentistry, differences between males and females regarding root morphology and association with gender specific diseases has also been reported.(53,93,94,95) In dental literature, many anatomical studies addressed different variations in root canal morphology according to ethnic background as well. (19,20,24,96–101) Alas, the data on both ethnicity and gender in relation to dentistry is scarce and therefore inconclusive in this day and age. (22,102) Very few studies have reported differences in the morphology of RCS, or number of roots in specific groups of teeth with regards to gender differences. (103-105)

CBCT studies performed to evaluate C-shaped canal configurations in maxillary molars and mandibular molars showed that females presented with a significantly higher prevalence rate compared to males in this anatomical variation. (93, 107,108) Another study to evaluate root canal morphology of upper first molars, reported a higher presence of two canals in mesio-buccal roots in males. (53) Also, in another CBCT study to evaluate fused-rooted maxillary molars and merged canals, females had a significantly higher prevalence of such anatomy. (108) A comprehensive literature search was conducted to find articles that evaluated the relationship between root canal anatomy and gender, and we were able to retrieved several articles comparing the root canal system anatomy only in a specific group of teeth.

The first *in vitro* study reported gender differences in all groups of teeth tested. It was published in 2004 by Sert and Bayirli and gave informative data about the Turkish population. (22) In another study, 1400 male and 1400 female extracted mandibular and maxillary permanent teeth were investigated and after evaluation, it was concluded that gender ought to be considered as a factor when performing the preoperative evaluation of non-surgical endodontic treatment.

There were only two published studies that addressed the association of genders with root canal system anatomy in all groups of teeth. The first comprehensive *in vivo* CBCT study was published in 2018, with a sample size of 12,325 teeth (4597 males and 7728 females) from 670 patients in Portuguese population. (102) A comparison between genders regarding the number of roots, number of root canals, and the RCS configuration was conducted. They concluded that differences are present within genders; with females showing lower numbers of roots per tooth and higher numbers of Vertucci type I configurations, while males were associated with a higher rate of three RCS configurations. The other *in vivo* CBCT study was published in 2019 in a Malaysian sub-population, which showed in general no significant differences in genders except few group of teeth. (109) In maxillary teeth, males showed significantly higher number of canals in second premolars and second molars. While in the mandibular arch, females showed a significantly higher prevalence of C-shaped configuration in second molar.

Very few *in vivo* CBCT anatomical studies addressed only a specific group of teeth in regard to gender, but not the whole arch, therefore a comprehensive picture could not be portrayed as to if gender did have a predilection on the configuration of the RCS. (53,110,111) Since majority of the *in vivo* studies were not elaborate, the information retrieved from them is too fragmented to put into theory. (53,103,110–116) Conducting *in vivo* studies with big sample sizes and for all teeth in the same individuals can fill the gaps and provide clinicians with precise results.

In a Saudi Arabian population, the tendency of maxillary first molars having 4 canals is higher in males (117) For mandibular canines, males showed a higher percentage of 2 roots compared to females, while no differences in canal configurations were observed. (120) In regards to C-shaped canal morphology in mandibular molars, Alfawaz *et al*. reported higher prevalence in females. (107)

I.6 Bilateral Symmetry of Root Canal Anatomy:

Literature only provides minimal data regarding bilateral symmetries in numbers of roots, number of canals and RCS configurations. (121–126) Anatomical symmetry of some groups of teeth with some variations in ethnical background and sample size have been reported however. Mandibular incisors, mandibular canines, mandibular and maxillary premolars have been investigated with regards to bilateral symmetry of root anatomy and canals morphology by means of CBCT in a limited number of studies. (121–125) In addition to this, other in-vivo CBCT studies were performed on root numbers and canals morphology of maxillary and mandibular molars to compare right with left side of the same tooth groups in the participants. (125,126) Even though, these studies have some potential limitations such as: only a specific group of teeth were evaluated, the available data presented a great range of symmetry and asymmetry between right and left teeth in the same patients.

In the Saudi Arabian population, Alqedairi *et al.* conducted a CBCT study and found bilateral symmetries in number of roots and canal configurations to be 91.2% and 85.3% for first and second maxillary premolars, respectively. (118) Another *in vivo* CBCT study in the same population, performed by Mashyakhy *et al.* evaluated bilateral symmetry in mandibular first molars and reported 100% symmetry in number of roots, 56.4% in number of canals, and for canal system configurations it was 54.1% in mesial roots and 47.6% in distal roots. (119) One of the most recent CBCT studies on mandibular canines reported that 97.7% of the teeth showed symmetrical number of roots and canal configurations. (120)

Knowledge about bilateral symmetry could be of clinical relevance when root canal treatment (RCT) is indicated in two contralateral teeth in the same individual. Up to our best knowledge, no study so far addressed bilateral symmetry of all groups of teeth in the same individuals and certainly not in a Saudi Arabian population.

I.7 Anatomical Variations in the Saudi Arabian Population:

Root canal morphology were studied widely in different populations showing some variations and similarities. (127) Most of these studies were done in Asian and western populations, where the findings did not match the Saudi population with a Middle Eastern ethnic background. Ahmed (2015) in a review article on the Saudi population, reported only 23 relevant studies that included laboratory, clinical/laboratory and case reports. (128) To date, only one *in vitro* CBCT study on maxillary first premolars and 4 *in vivo* CBCT studies on maxillary first molars, maxillary premolars and mandibular first and second molars have been reported. (107,117–119)

All these studies were carried out with different methodologies (*in vitro* and *in vivo* techniques) in the Saudi Arabian population in different teeth groups. They showed, in general, an agreement with international teeth morphological studies. The drawbacks of most of these studies were a lack of homogeneity, small sample sizes, lack of information regarding gender and location of teeth in the jaw. In addition, these studies did not report all teeth groups but focused on some groups of teeth and certain anatomical variations. Also, only a few of them investigated the impact of gender, age and bilateral symmetry on root canal morphology.

Therefore, the current *in vivo* CBCT study focused on all teeth groups with a large sample size. Gender differences and bilateral symmetry were addressed for better understanding of teeth morphology and its association with the variables.

II. OBJECTIVES AND HYPOTHESES

Ii.1. Objectives

The objectives of this *in vivo* CBCT study in a Saudi Arabian population were to:

- Evaluate the external anatomy and internal morphology of all permanent teeth except 3^{rd} molars in regard to:

    a. Number of roots

    b. Number of canals

    c. Canal system configurations according to the Vertucci classification

- Gender influence on teeth morphology

- Bilateral symmetry of teeth morphology within the same patients

II.2. Null Hypotheses:

- The first null hypothesis was that there is no difference between genders in regard to the number of roots, number of canals and canal configurations.

- The second null hypothesis was that there is no difference between right and left teeth within the same patients in regard to the number of roots, number of canals and canal configurations.

III. METHODOLOGY

III.1 The Sample:

A total of 208 Saudi Arabian patients (100 (48%) males and 108 (52%) females) with mean age of 28.74±9.56 years (median= 26 years) ranging from 17 to 59 years, with (5254) maxillary and mandibular teeth were tested in this study. More details about the screened, excluded and evaluated maxillary and mandibular teeth are presented in Tables 1-3. The CBCT scans were retrieved from the database of College of Dentistry, Jazan University, Jazan, Saudi Arabia from the period 2016 to 2018. The study protocol was approved by the local institutional review board (IRB: REC39/6-S011). Teeth with fully developed roots and closed apices were included in the study. Previously root treated or root canal treatment–initiated teeth, teeth with periapical lesions, calcification or resorptions, and distorted CBCT images were excluded.

III.2 CBCT Scans:

The CBCT machine used in this retrospective cross-sectional *in vivo* study was 3D Accuitomo 170 (MORITA, Japan) and the scanning parameters were constant for all patients as follows: FOV 170_120 mm, 90 Kv, 5-8 mA, 17.5 seconds exposure time and 0.25mm voxel size. All CBCT images were processed and reconstructed using Morita's i-Dixel 3D imaging software. Serial axial, coronal and sagittal sections were acquired to evaluate number of roots, number of the canals and root canal system configuration on the basis of Vertucci's classification. First, the sectioning was oriented to be parallel to the long axis of root canal with 1mm slice thickness. Then the projections were examined by scrolling the images in coronal-apical direction for axial sections and from mesial to distal for parasagittal sections. A careful examination was obtained by optimal visualization using all the software features, such as zooming, change in contrast and brightness. The author evaluated all the scans twice with 4-week intervals.

III.3 Data Analysis:

The collected data were introduced to the Statistical Package of Social Sciences software program for Windows (SPSS V25; IBM, Chicago, IL), coded, and analyzed. The primary outcome of this study was to identify the number of roots, number of canals and canal system configurations of all permanent teeth except 3rd molars. Differences by gender and bilateral symmetry (right and left) were assessed for the above-mentioned variables. The results were expressed as frequencies and percentages with 95% confidence interval (CI). The Z-test was used for differences in the independent proportions, Chi-squared test was used for the differences between both genders (male and female) and Cohen's Kappa test was used for bilateral symmetry. Kappa test was also used for intra-rater reliability. Level of significance for all statistical tests was set at $p\text{-value} < 0.05$.

IV. RESULTS

For inter-rater reliability, two readings of 30% of the study sample were taken with an interval period of 4 weeks. Cohen's Kappa test revealed agreement of measurement with a value of 0.85 and $P < 0.001$.

Iv.1. External Anatomy and Internal Morphology:

IV.1.1. Maxillary Teeth:

Central Incisors

A total of 384 maxillary central incisors were evaluated. All teeth (100%) had one root, one canal, and Vertucci type I (Table 4).

Lateral Incisors

Three hundred and eighty six maxillary lateral incisors were screened for the purpose of this study. All of them (100%) had one root, one canal, and Vertucci type I (Table 5).

Canines

A total of 384 maxillary canine teeth were evaluated. All teeth (100%) had one root. Out of them, 380 (99.0%) teeth had one canal, and 4 (1.0%) teeth had 2 canals. Similarly, 380 (99.0%) teeth had Vertucci type I, and 4 (1.0%) teeth had Vertucci type III (Table 6).

First Premolars

Among all screened teeth, 351 maxillary first premolars were investigated. Out of them, 143 (40.7%) teeth had one root, 202 (57.5%) teeth had 2 roots, and 6 (1.7%) teeth had 3 roots. Regarding number of canals, majority of teeth (93.2%) had 2 canals, 3.7% had one canal, 2.6% had 3 canals, and only 0.6% (2 teeth) had 4 canals. Different Vertucci types were observed in the maxillary first premolars. About two thirds (63.8%) of teeth had Vertucci type IV, 14.8% had Vertucci type V, 7.7% had Vertucci type III, and 6.8% had Vertucci type II. Other different types of canal configuration were found in 2.8% of teeth. There were three teeth with 2 roots, 3 canals, and C-shape configuration (Table 7).

Second Premolars

Out of 359 evaluated maxillary second premolars, 316 (88.0%) teeth had one root, and 43 (12.0%) teeth had 2 roots. One canal was observed in 137 (38.2%) teeth while, 2 canals in 219 (61.0%) teeth, and 3 teeth were found with extra canal (had 3 canals). More than one third (38.2%) of teeth had Vertucci type I, 19.2% had Vertucci type IV, 15.3% had Vertucci type III, and 12.3% had Vertucci type V. Three teeth (0.8%) had different types of canal configuration. More details are presented in Table 8.

First Molars

A total of 354 maxillary first molars were evaluated. Out of them, 24 (6.8%) teeth had fused roots and 330 (93.2) teeth had non–fused roots (3 roots). Amongst the teeth with non-fused roots, 283 (85.8%) teeth had 4 canals and 47 (14.2%) teeth had 3 canals. Nearly half of teeth (48.2%) had Vertucci type IV in mesio-buccal roots, 35.2% had Vertucci type II, and 13.6% had Vertucci type I. Vertucci types III, V, and VI were found in less percentages (1.8%, 0.6%, and 0.6%, respectively). Regarding canal configuration in disto-buccal and palatal roots, all teeth (100%) had Vertucci type I (Table 9).

Amongst teeth with fused roots (n= 24), 6 (25%) teeth had one root and 18 (75%) teeth had 2 roots. Out of them, 22 (91.7%) teeth had non-merged canals and 2 (8.3%) teeth had merged canals and C-shaped configuration. For teeth with non-merged canals (n= 22), 17 (68.2%) teeth had 4 canals and 7 (31.8%) teeth had 3 canals. For canal configuration in mesio-buccal roots, 7 (31.8%) teeth had Vertucci type I, 10 (45.5%) teeth had Vertucci type II, 4 (18.2%) teeth had Vertucci type IV, and only one (4.5%) tooth had Vertucci type V, All teeth (100%) had Vertucci type I in disto-buccal and palatal roots (Table 10).

Second Molars

A total of 372 maxillary second molars were investigated. Out of them, 78 (21.0%) teeth had fused roots, 292 (78.5%) had non-fused roots, and 2 (0.5%) teeth had extra palatal root (had 4 roots). Amongst teeth with non-fused roots (n= 292), 98 (33.6%) had 3 canals and 199 (66.4%) teeth had 4 canals. All teeth (100%) had Vertucci type I in disto-buccal and palatal roots. However, regarding canal configuration in mesio-buccal roots, 32.9% of teeth had Vertucci type I, 32.5% had Vertucci type IV, and 26.4% had Vertucci type II. All other Vertucci types (III, V, and VI) were found in 8.2 % of teeth (Table 11).

Amongst teeth with fused roots (n= 78), 53 (67.9%) teeth were with non-merged canals and 25 (32.1%) teeth had merged canals and C-shaped configuration. Regarding number of roots, 24 (30.8%) teeth had one root (out of them, 17 teeth had merged canals) and 54 (69.2%) teeth had 2 roots (out of them, 8 teeth had merged canals). Out of teeth with non-merged canals (n= 53), 38 (71.7%) teeth had 3 canals and 15 (28.3%) teeth had 4 canals. All teeth with non-merged canals (100%) had Vertucci type I in disto-buccal and palatal roots. Whilst, out of them, 71.7% had Vertucci type I, 17.0% had Vertucci type IV, 9.4% had Vertucci type II, and 1.9% had Vertucci type V in mesio-buccal root (Table 12).

IV.1.2. Mandibular Teeth:

Central Incisors

A total of 410 mandibular central incisors teeth (right and left) were evaluated. All teeth (100%) had one root. Out of the total sample, there were 302 (73.7%) teeth had one canal and 108 (26.3%) teeth had 2 canals. Similarly, there were 302 (73.7%) teeth found with Vertucci Type I and 108 (26.3%) teeth with Vertucci Type III (Table 13).

Lateral Incisors

A total of 412 mandibular lateral incisors (right and left) were evaluated. Out of them, 410 (99.5%) teeth had one root, and only 2 (0.5%) teeth had 2 roots. Teeth with one canal accounted 285 (69.2%) teeth while, 127 (30.8%) teeth were found with 2 canals. Vertucci type I was found in 285 (69.2%) teeth while, 123 (29.8%) teeth had Vertucci type III, and only 4 (1.0%) teeth had Vertucci type V (Table 14).

Canines

Out of 410 mandibular canines (left and right) evaluated by CBCT, 339 (97.3%) teeth had one root, 11 (2.7%) teeth had 2 roots. Whereas 372 (90.7%) teeth had one canal, and 38 (9.3%) teeth had 2 canals. Vertucci type I was found in 372 (90.7%) teeth while, 25 (6.1%) teeth had Vertucci type III, and 13 (3.2%) teeth had Vertucci type V (Table 15).

First Premolars

Amongst the evaluated teeth there were 397 mandibular first premolars. Out of them, 395 (99.5%) teeth had one root and only 2 (0.5%) teeth had 2 roots. More than two thirds of the sample (69.5%) had one canal, 117 (29.5%) had 2 canals, and only 4 (1.0%) teeth had 3 canals. Regarding canal configuration, 276 (69.5%) teeth had Vertucci type I, 25 (6.3%) teeth had

Vertucci type III, 92 (23.2%) teeth had Vertucci type V, and only one (0.3%) tooth had Vertucci type VII. However, 3 (0.8%) teeth had different type of configuration. Only 6 (1.5%) had C-shape configuration. All of them had one root, and out of them 4 teeth had 2 canals and 2 teeth had 3 canals. Similarly, 4 teeth had Vertucci type V and 2 teeth had different types of canal configuration (Table 16).

Second Premolars

Three hundred and seventy nine mandibular second premolars were evaluated. All teeth (100%) had one root. Out of them, 367 (96.8%) teeth had one canal, 8 (2.1%) teeth had 2 canals, and 4 (1.1%) teeth had 3 canals. The majority of the sample (96.8%) had Vertucci type I, 6 (1.6%) teeth had Vertucci type III, 3 (0.8%) had Vertucci type V, and 3 (0.8%) teeth had different types of canal configuration. Out of the sample, there were 3 (0.8%) teeth had one root, 3 canals, and C-shape configuration (Table 17).

First Molars

A total of 290 mandibular first molars were evaluated. The majority (94.5%) had 2 roots, and 16 (5.5%) teeth had 3 roots. Only 2 (0.7%) teeth had 2 canals, 187 (64.5) teeth had 3 canals, and 101 (34.8%) teeth had 4 canals. More than half of the sample (57.9%) had Vertucci type IV in mesial canals. Whereas, 105 (36.2%) teeth had Vertucci type II. However, Vertucci types I, III, and V were found in less proportions. In contrast, 200 (69.0%) teeth had Vertucci type I in distal canals, 50 (17.2%) teeth had Vertucci type III while, Vertucci types II, IV, and V were found in less proportions. There were 14 (4.8%) teeth had 3 roots and 4 canals (Table 18).

Second Molars

A total of 366 mandibular second molars were evaluated. Out of them, 328 (89.6%) teeth had 2 roots, 31 (8.5%) teeth had one root (2 teeth had fused roots without C-shape configuration and 29 teeth had fused roots with C-shape configuration), and 7 (1.9%) teeth had 3 roots. Amongst teeth with normal canals (N= 337), there were 294 (87.2%) teeth had 3 canals, 23 (6.8%) teeth had 2 canals, and 20 (5.9%) teeth had 4 canals. Frequency of Vertucci types in mesial canals was the highest for Vertucci type IV (39.5%), followed by Vertucci type II (25.5%), and the least was for Vertucci type I (6.2%). Dissimilarly, Vertucci type I was the most frequent type in distal canals (95.5%), and no Vertucci type IV was detected (Table 19).

IV.2. Gender Differences:

IV.2.1. Maxillary and Mandibular Teeth:

In general, there were no significant differences between both genders in relation to number of roots of maxillary and mandibular teeth separately (P= 0.315 and P= 0.100, respectively) as well as no significant difference was found for all maxillary and mandibular teeth together (P= 0.064). However, significant difference was found between males and females in relation to number of canals of maxillary teeth (P= 0.014) where teeth with 1 or 3 canals were found more frequent in females than in males while, teeth with 2 or 4 canals were found more frequent in males than in females. For mandibular teeth, the significant level of difference between males and females in relation to number of canals was at the cut-off point (P= 0.050). For all maxillary and mandibular teeth together, the distribution among both genders in relation to number of canals was not significant (P= 0.082) (Table 20 & 21) (Figure 2 & 3).

Difference between both genders with regard to canal configuration of maxillary roots was highly statistically significant (P< 0.001). Roots with Vertucci type I, III, and V were more frequent in females than in males while, roots with Vertucci type II, IV, VI, and VII were more frequent in males than in females. For mandibular teeth, difference between males and females in relation canal configuration of anterior and premolar teeth was significant (P= 0.016) while, the difference was not significant when related to the canal configuration of mesial roots of 1st and 2nd molars (P= 0.205). However, the difference between males and females was highly significant when related to canal configuration of distal roots of 1st and 2nd molars together (P< 0.001) (Figures 4 & 5).

IV.2.2. Maxillary Teeth:

Central Incisors

In comparison between males and females, 200 (52.1%) teeth were found in females and 184 (47.9%) teeth in males. However, the significance of difference could not be computed because all teeth (100%) in males and all teeth (100%) in females had one root, one canal, and Vertucci type I (Table 22).

Lateral Incisors

Although number of teeth in females was higher than in males (200 (52.1%) teeth in females compared to 184 (47.9%) teeth in males), the significance of difference was not applicable because all teeth (100%) in females and all teeth (100%) in males had one root, one canal, and Vertucci type I (Table 23).

Canines

There were 200 (52%) teeth in females and 180 (48%) teeth in males. All teeth (100%) in both genders had one root. All teeth (100%) in females had one canal while, in males, 180 (97.8%) teeth had one canal, and 4 (2.2%) teeth had 2 canals, with no significant difference between both genders (P= 0.052). Similarly, all teeth (100%) in females had Vertucci type I while, 180

(97.8%) teeth in males had Vertucci type I, and 4 (2.2%) teeth had Vertucci type III. No significant difference between both genders was found (P= 0.052) (Table 24).

First Premolars

Out of 176 (50.1% of all maxillary first premolars) teeth in females, 53.4% had 2 roots, 45.5% had one root, and 1.1% (2 teeth) had 3 roots. However, 108 (61.7%) out of 175 teeth in males had 2 roots, 36% had one root, and 2.3% had 3 roots. The difference between both genders was not statistically significant (P= 0.161). The majority of teeth in both genders (96.0% of teeth in females and 90.3% of teeth in males) had 2 canals. No teeth in females and 2 teeth in males had 4 canals. Teeth with one canal and 3 canals were found in less percentages. Similarly, no significant difference was found regarding number of canals (P= 0.125). Significant difference was found between both genders in relation to Vertucci types (P< 0.001). More than half of teeth (59.7%) in females had Vertucci type IV, followed by Vertucci type V (21.0%), and Vertucci type III (11.4%). In males, 68.0% of teeth had Vertucci type IV, followed by Vertucci type II (10.3%), and Vertucci type V (8.6%) (Table 25).

Second Premolars

Distribution of teeth among both genders was approximately similar (50.7% in males compared to 49.3% in females). The majority of teeth in both genders had one root with no significant difference (P= 1.000). About two thirds (65.9%) of teeth in males and about half of teeth (55.9%) in females had 2 canals with statistically significant difference (P= 0.046). Vertucci type I was found in 62 (34.1%) teeth in males followed by Vertucci type IV which was found in 41 (22.5%) teeth. However, Vertucci type III was found in 31 (17.5%) teeth in females followed by Vertucci type IV which was found in 28 (15.8%) teeth. Even though, no significant difference between males and females was found (P= 0.064) (Table 26).

First Molars

In comparison between both genders, all teeth in males (n= 151, representing 45.76% of the total sample) and all teeth in females (n= 179, representing 54.24% of the total sample) had 3 roots and Vertucci type I in disto-buccal and palatal roots. Test of significant was not applicable. However, significant difference between males and females was found with regards to number of canals (p= 0.007). Teeth with 4 canals were found in higher percentage in males than in females (91.4% in males compared to 81.0% in females) while, 19.0% of teeth in females and 8.6% of teeth in males had 3 canals. Regarding Vertucci types in mesio-buccal roots, the majority of teeth in males and females (52.3% and 44.7%, respectively) had Vertucci type IV followed Vertucci type II (35.8% of teeth in males and 34.6% of teeth in females). No significant difference between both genders was found (P= 0.068). More details are shown in Table 27.

Second Molars

All teeth in males (n= 144, representing 49.0% of the total sample) and all teeth in females (n= 148, representing 51.0% of the total sample) had one root, and Vertucci type I in disto-buccal and palatal roots. A significant difference was found between both genders in relation to number of canals (P= 0.047). More than two thirds (72.2%) of teeth in males had 4 canals and 27.8% had 3 canals while, 60.8% of teeth in females had 4 canals and 39.2% had 3 canals. The most frequent Vertucci type in mesio-buccal roots in males was Vertucci type IV (43.8% of teeth), followed by Vertucci type I (26.4% of teeth), and Vertucci type II (25.7% of teeth). However, this is was not the case in females where the most frequent Vertucci type in mesio-buccal roots was Vertucci type I (39.2% of teeth), followed by Vertucci type II (27.0% of teeth), and Vertucci type IV (21.6% of teeth). Highly significant difference between males and females was found (P< 0.001). More details are illustrated in Table 28.

IV.2.3. Mandibular Teeth:

Central Incisors

Regarding comparison between males and females, both genders had all their mandibular central incisors with one root. Test of significance could not be computed. Females had more teeth with one canal (170 teeth, representing 79.4% of teeth in females) compared to males who had 132 teeth (67.3% of teeth in males) with one canal. However, males had higher number of teeth with 2 canals (64 teeth, representing 32.7% of teeth in males) than females who had only 44 teeth (20.6% of teeth in females) with 2 canals. The difference was statistically significant (P= 0.007). Similarly, there was significant difference (P= 0.007) in relation to Vertucci classification among both genders with the same percentages applied (Table 29).

Lateral Incisors

Amongst 214 teeth in females, there were 213 (99.5%) teeth with one root, and only one tooth (0.5%) was found with 2 roots. Similarly, amongst 198 teeth in males, there were 197 (99.5%) teeth with one root, and only one tooth (0.5%) was found with 2 roots. No significant difference was observed (P= 1.000). One hundred and fifty two (71.0%) teeth in females and 133 (67.2%) in males had one canals while, 62 (29.0%) teeth in females and 65 (32.8%) teeth in males had 2 canals, with no significant difference (P= 0.455). Regarding Vertucci classification, 133 (67.2%) teeth in males had Vertucci type I, 63 (31.8%) teeth had Vertucci type III, and only 2 (1.0%) teeth had Vertucci type V. In females, 152 (71.0%) teeth had Vertucci type I, 60 (28.0%) teeth had Vertucci type III, and only 2 (1.0%) teeth had Vertucci type V. No significant difference was found between both genders (P= 0.698) (Table 30).

Canines

Amongst 197 mandibular canines in males there were 195 (99.0%) with one root and 2 (1.0%) teeth with 2 roots while, amongst 213 mandibular canines in females there were 204 (95.8%) teeth with one root, and 9 (4.2%) teeth with 2 roots. No significant difference was found between both genders (P= 0.064). One hundred and eighty four (93.4%) mandibular canines in males had one canal while, 188 (88.3%) mandibular canines in females had one canal. No significant difference was observed between both genders (P= 0.088). Vertucci type I was more frequent in males than in females (93.4% compared to 88.3%) while, Vertucci types III and V were more frequent in females than in males. The significant level of difference between both genders was near the cut-off point (P= 0.049) (Table 31).

First Premolars

Although teeth with one root were higher in females than in males (100% compared to 98.9%), no significant difference between both genders was found (P= 0.224). Similarly, no significant difference (P= 0.229) was found between both genders with regard to number of canals. However, significant difference (P= 0.012) was found between both genders in relation to canal configuration. Teeth with Vertucci types I and V were higher in females than in males while, teeth with Vertucci type III were higher in males (Table 32).

Second Premolars

Regarding comparison between both genders, all teeth (100.0%) in males and all teeth (100.0%) in females had one root. No significant difference (P= 0.055) was found between both genders with regard to number of canals although teeth with one canal were higher in females compared to males (99.0% compared to 94.7%, respectively). Similarly, no significant difference (P= 0.098) was found in relation to canal configuration. Even though teeth with Vertucci type I in females were 189 (99.0%) and 178 (94.7%) in males (Table 33).

First Molars

Most teeth in both genders had 2 roots and 3 canals with no significant differences (P= 0.305 and P= 0.987, respectively). Similarly, no significant difference (P= 0.471) was found between both genders with regard to Vertucci types in mesial canals. However, significant difference (P= 0.005) was found between both genders in relation to Vertucci types in distal canals, with more frequent of Vertucci types II and III in females and Vertucci type V in males (Table 34).

Second Molars

As illustrated in Table 35, no significant differences were found between both genders in relation to number of roots (P= 0.162, with higher proportion of teeth with 2 roots in males), number of canals (P= 0.253, with higher proportion of teeth with 3 canals in males), Vertucci types in mesial canals (P= 0.336, with higher proportion of teeth with Vertucci type IV in males and Vertucci type II in females), and Vertucci types in distal canals (P= 0.112, with higher proportion of teeth with Vertucci type I in females).

IV.3. Bilateral Symmetry:

IV.3.1. Maxillary Teeth:

The results of the total bilateral symmetry of the maxillary teeth are presented in Tables 36 & 37.

Central Incisors

For bilateral symmetry, 185 (88.9% out of the total sample) participants had maxillary central incisors in both sides (right and left). The total bilateral symmetry was 100%, all 185 participants (100%) had one root, one canal, and Vertucci type I in both sides (Table 38 & Figure 6).

Lateral Incisors

For bilateral symmetry, 184 (88.5% out of the total sample) participants had right and left maxillary lateral incisors. The total bilateral symmetry was 100%, all 185 participants (100%). All participants (100%) had one root, one canal, and Vertucci type I in both sides (Table 39).

Canines

As shown in Table 40, all the 183 (88.0% of the total sample) participants, who had maxillary canines in both sides, had one root in both right and left sides (100% bilateral symmetry). However, bilateral symmetry for number of canals was 98.9% ($P < 0.001$) where 180 (98.4%) participants had one canal in both sides, and one participant (0.5%) had 2 canals in both sides. Similarly, the bilateral symmetry for Vertucci types was 98.9% ($P < 0.001$). Out of 183 participants, 180 (98.4%) participants had Vertucci type I in both sides while, one (0.5%) participant had Vertucci type III in both sides.

First Premolars

Table 41 shows the bilateral symmetry among participants with both right and left maxillary first premolars. Out of 208 participants, 162 (77.9%) participants had maxillary first premolars in both sides. Bilateral symmetry for number of roots was 85.1% (P< 0.001) while, it was 93.2% (P< 0.001) for number of canals, and 83.0% (P< 0.001) for Vertucci types. A bit more than half of participants (51.2%) had 2 roots in both sides while, 90.8% of participants had 2 canals in both sides, and 59.3% of participants had Vertucci type IV in both sides. The other sub-categories were found in less percentages.

Second Premolars

Bilateral symmetry according to the study variables is shown in Table 42. Out of 208 participants, 165 (79.3%) participants had maxillary second molars in both right and left sides. Bilateral symmetry for number of roots was 93% (P< 0.001). The majority of participants had one root in both sides while, 8.6% had 2 roots in both sides. Bilateral symmetry for number of canals was 83% (P< 0.001). About half (52.7%) of participants had 2 canals in both sides, 29.7% had one canal, and one participant (0.6%) had 3 canals in both sides. Bilateral symmetry for canal configuration was less frequent, accounting for 112 participants (67.8%, P< 0.001). Less than one third of participants (29.7%) had symmetrical Vertucci type I, 6.7% had symmetrical Vertucci types II and V, 9.1% for Vertucci type III, 14.5% for Vertucci type IV, and 0.6% for Vertucci types VI and other canal configuration (Figure 7).

First Molars

One hundred and forty three out of 208 participants (68.8%) had maxillary first molars in both sides (right and left). Bilateral symmetry for number of roots and Vertucci types in disto-buccal and palatal roots was 100% each. All participants had 3 roots and Vertucci type I in distobuccal and palatal roots in both sides. Out of 143 participants, 137 participants had bilateral symmetry for number of canals (95.8%; $P < 0.001$). Eighteen (12.6%) participants had symmetrical 3 canals, and 119 (83.2%) participants had symmetrical 4 canals. Only Vertucci types I, II, and IV were symmetrical in mesio-buccal roots. Out of 143 participants, 116 participants had symmetrical Vertucci types in mesio-buccal roots in both sides (81.1%; $P < 0.001$). This was 17 (11.9%) participants for Vertucci type I, 40 (28.0%) for Vertucci type II, and 59 (41.3%) for Vertucci type IV (Table 43).

Second Molars

Out of the evaluated participants (n=208), 127 (61.1%) participants had bilateral maxillary second molars. All participants had 100% bilateral symmetry for number of roots and Vertucci types (type I) in disto-buccal and palatal roots. However, bilateral symmetry for number of canals was 81.1% ($P < 0.001$). There were 30 (23.7%) participants which had 3 canals and 73 (57.5%) participants which had 4 canals in their both right and left maxillary second molars. In relation to canal configuration in mesio-buccal roots, the bilateral symmetry was 69.3% ($P < 0.001$) where 23.7% of participants had symmetrical Vertucci type I, 16.5% had symmetrical Vertucci type II, and 25.2% had Vertucci type IV. The other Vertucci types were found in less percentages (Table 44).

IV.3.2. Mandibular Teeth:

The results of the total bilateral symmetry of the mandibular teeth are presented in Tables 45-47.

Central Incisors

For bilateral symmetry, out of 208 participants, 205 (98.6%) participants were found with bilateral (both right and left sides) mandibular central incisors. In general, bilateral symmetry for number of roots was 100% while, it was 91.2% (P< 0.001) for number of canals, and also 91.2% (P< 0.001) for Vertucci classification. All of participants (100%) had one root in both right and left sides. Out of them, 142 (69.3%) participants had one canal in both sides, and 45 (21.9%) participants had 2 canals in both sides. Similarly, significant symmetry of Vertucci types was found with the same percentages applied (Table 48).

Lateral Incisors

Out of 204 (98.1% of all participants) participants with both right and left mandibular lateral incisors, 202 (99.0%) participants had one root in both sides. Bilateral symmetry for number of canals was 85.8% (P< 0.001), where 127 (62.3%) participants had one canal in both sides, and 48 (23.5%) participants had 2 canals in both sides. For Vertucci classification, bilateral symmetry was 85.3% (P< 0.001), where 127 (62.3%) participants had Vertucci type I in both sides, 46 (22.5%) participants had Vertucci type III, and one (0.5) participant had Vertucci type V in both sides (Table 49).

Canines

Two hundred and two out of 208 participants (97.1%) had both right and left mandibular canines. The total bilateral symmetry for number of roots was 95.5% (P= 0.023) where the majority of participants (95.1%) had one root in both sides while, only one participant (0.5%) had 2 roots in both sides. Bilateral symmetry for number of canals was 91.1% (P< 0.001) where 86.1% of participants had one canal in both sides, and only 4.9% of participants had 2 canals in both sides. Regarding canal configuration, the total bilateral symmetry was 90.1% (P< 0.001) where 86.1% of participants had Vertucci type I in both sides, 3.5% of participants had Vertucci type III in both sides, and only one participant (0.5%) had Vertucci type V in both sides (Table 50 & Figure 8).

First Premolars

Amongst the 208 participants, 194 (93.3%) participants had mandibular first premolars in both sides (right and left). Among them, the total bilateral symmetry for number of roots was 99% where 192 (99%) participants had one root in both sides while, no participant had 2 roots in both sides. The total bilateral symmetry for number of canals was 87.1% (P= 0.001) where 122 (62.9%) participants had one canal in both sides, 46 (23.7%) participants had 2 canals in both sides, and only one (0.5%) participant had 3 canals in both sides. Regarding canal configuration, the total bilateral symmetry was 83.5% (P< 0.001) where 122 (62.9%) participants had Vertucci type I in both sides, 5 (2.6%) participants had Vertucci type III in both sides, and 35 (18.0%) participants had Vertucci type V in both sides. However, Vertucci type VII was found in only one (0.5%) participant in one side (right side, and no symmetry was found for the other types of canal configuration (Table 51).

Second Premolars

Out of 208 participants, there were 179 (86.1%) participants had mandibular second premolars in both sides (right and left). All participants (100.0%) had one root in both sides. Bilateral symmetry for number of canals was 83.7% (P< 0.001) where 171 (95.5%) participants had one canal in both sides, 2 (1.1%) participants had 2 canals in both sides, and only one (0.6%) participant had 3 canals in both sides. The total bilateral symmetry for canal configuration was 82.7% (P< 0.001). Vertucci type I in both sides was found in 171 (95.5%) participants while, Vertucci type III in both sides was found in one (0.6%) participant only. No bilateral symmetry was for Vertucci type V. Also, the other different types of canal configuration were not symmetrical among the participants (Table 52).

First Molars

One hundred and twenty one participant (58.2% of 208 participants) had mandibular first molars in both sides. Bilateral symmetry for number of roots was 99.2% (P< 0.001) while, it was 89.3% (P< 0.001) for number of canals, 87.6% (P< 0.001) for Vertucci types in mesial canals, and 82.6% (P< 0.001) for Vertucci types in distal canals. One hundred and fourteen (94.2%) participants had 2 roots in both sides, and 6 (5.0%) participants had 3 roots in both sides. No symmetry was found for teeth with 2 canals while, 60.3% of participants had 3 canals in both sides and 28.9% of participants had 4 canals in both sides. Similarly, no symmetry was found among participant regarding Vertucci types I and III in mesial canals while, more than half (52.9%) of participants had symmetrical Vertucci type IV, 31.4% of participants had symmetrical Vertucci type II, and only 4 (3.3%) participants had symmetrical Vertucci type V. The majority of participants (63.6%) had bilateral symmetry of Vertucci type I in distal canals. Whereas less proportions of participants had bilateral symmetry for the other Vertucci types in distal canals (Table 53).

Second Molars

Amongst 208 participants, 155 (74.5%) participants had both right and left mandibular second molars. For them, the total bilateral symmetry for number of roots was 98.1% (P< 0.001) where most participants (96.2%) had 2 roots in both sides. Regarding number of canals, the total bilateral symmetry was 92.9% (P< 0.001) where the majority of participants (84.5%) had 3 canals in both sides, 4.5% of participants had 4 canals and 3.9% of participants had 2 canals in both sides. The total bilateral symmetry for Vertucci types in mesial canals was 74.2% (P< 0.001). About one third (34.2%) of participants had Vertucci type IV in both sides, 18.7% and 9.7% of participants had Vertucci types II and III, respectively, and the least symmetrical type was Vertucci type I (3.9%). In relation to Vertucci types in distal canals, the total bilateral symmetry was 97.4% ($P < 0.001$) where the majority of participants (94.8%) had symmetrical Vertucci type I while, the least symmetrical Vertucci type was type II (0.6% of participants), and no Vertucci type III was found in the right side among participants (Table 54).

V. DISCUSSION

Gender Differences:

In the present study, a comparison between males and females regarding number of roots, number of root canals, and root canal configurations according to Vertucci's classification was performed. Regarding number of roots, no significant differences were found between genders in all 14 groups of teeth. This is in agreement with an *in vivo* CBCT study of all permanent dentition in a Malaysian sub–population. (109) However, another comprehensive *in vivo* CBCT study in a Portuguese population reported significant differences between genders in four of 14 tooth groups with females showing lower numbers of roots per tooth in maxillary first premolars, and second molars while, mandibular canines showed the opposite. (102) In a Saudi population, anatomical studies using *in-vivo* CBCT are consistent with our findings with no significant differences between genders in number of roots of maxillary premolars, maxillary first molars, mandibular canines, and mandibular first molars. (117-120) Two other *in vivo* CBCT studies in different populations reported some significant differences between genders in number of roots of maxillary and mandibular first and second premolars, where both found that males had higher number of 2-rooted premolars, while females had higher number of single-rooted premolars. (105,130) Also, the same was found in other CBCT studies on maxillary and mandibular molars, where females had lower number of roots compared to males. (113,114,131) In the literature, there is a tendency of females having a lesser number of roots per tooth. Many studies support the latter stance but there are ones that say otherwise. (111–113)

Generally, the internal canal morphology follows the external anatomy of the root, and that might have an impact on the lower number of roots in different genders. In regards to number of canals in the present study, only 3 groups out of 14 teeth groups (two in maxillary teeth and one in mandibular teeth) showed significant differences between genders. Maxillary first and second molars had 4 canals with higher percentage in males than in females. However, in mandibular teeth groups, only central incisors showed statistically significant differences (*P*= 0.007), where males had higher number of teeth with 2 canals compared to females. In a study of all permanent dentition in a Malaysian sub-population (109), only 2 groups of teeth (second premolars and second molars) showed that males had significantly higher number of canals compared to females while the rest of teeth groups had no significant differences. In the Saudi population, some studies reported similar results to our findings, where in maxillary first molars males had a significant higher number of canals compared to females. (117) However, other studies reported that maxillary premolars, mandibular canines, and mandibular first molars had no significant differences between genders. (118)

In the present study, we also investigated the association between genders with RCS configurations. In total, Maxillary teeth showed highly statistically significant differences ($P < 0.001$) between both genders with regard to canals configurations where, roots with Vertucci type II, IV, VI, and VII were more frequent in males than in females while, roots with Vertucci type I, III, and V were more frequent in females. Whereas, only 2 groups (first premolars and second molars) out of 7 teeth groups of maxillary teeth showed statistically significant differences between both genders in relation to canals configurations. These findings are generally consistent with a study in a Portuguese population where all teeth showed higher prevalence of Vertucci type I configurations in females, being highly statistically significant in both maxillary premolars. (102) However, in a Malaysian subpopulation there were no statistically significant differences between genders regarding RCS configurations in all teeth groups. (109) In addition, a study of maxillary first premolars in a Saudi population (118) showed no differences between genders in regards to canal configuration, while the findings the German subpopulation study (130) is in agreement with our results where Vertucci type I for maxillary first premolars where higher in females. Another study in a Korean population (53) on maxillary second molars, mesial buccal roots showed similar canal configurations compared to our study with higher prevalence of Vertucci type I in females, however, the differences was not statistically significant. In contrast, other studies from different populations reported (with no significant differences) higher prevalence of Vertucci type I in mesial buccal roots of both maxillary molars in males compared to females. (113,116) Differences in findings of the above mentioned studies might be related to ethnic background and/or sample size.

In mandibular teeth, generally there were significant differences between males and females in relation to canal configuration of anterior and premolar teeth (P= 0.016), and distal roots of 1st and 2nd molars together (P< 0.001). Specifically, only three groups out of seven teeth groups showed statistically significant differences between genders in regards to canal configurations. Vertucci type I canals configuration was significantly higher in females in mandibular central incisors and first premolars. While in distal roots of mandibular first molars, Vertucci types II and III were highly significant in females and Vertucci type V in males. In a Portuguese study, results showed differences in 5 of the 7 groups of mandibular teeth with a higher tendency for Vertucci type I in females while in central incisors and first premolars the differences were significant with females who had higher number of Vertucci type I, but in canines males had significantly higher Vertucci type I. (102) These results are generally in agreement with our findings. In another comprehensive CBCT study, the authors found no statistical differences between genders for canal configuration, except that females possessed a significant higher number of second molar teeth with C-shaped morphology while, in our study mandibular second molars with C-shaped canals had no gender association. (109) In the Saudi population, Vertucci type I in mandibular canines in female patients was significantly higher than males, which is contrary to our findings where no statistical difference between genders was found. (120) Another study in the same population on mandibular first molars showed no association between genders and canals configurations, whereas, our study showed a significant difference in distal roots canal systems, with more frequent of Vertucci types II and III in females and Vertucci type V in males. (119) These inconsistencies between studies in the same Saudi population could be related to the region in the same country where the sample was obtained and the sample size. In addition, studies from different populations showed females have higher percentage of Vertucci type I compared to males in mandibular central incisors and first premolars. (124) All the above mentioned studies were *in vivo* CBCT anatomical studies and addressed genders differences related to root and root morphology.

The present *in-vivo* CBCT study is the first comprehensive study conducted in a Saudi Arabian population evaluating all teeth groups in the same individuals with a large sample. Results from literature led to a hypothesis that males tend to possess higher number of roots and root canals than females regardless the statistical significance of the results. However, previous studies that were performed on specific teeth groups might not have remarked this tendency. (102) So far, only 3 studies, including the current study, which used *in vivo* CBCT on all teeth groups partially accepted this hypothesis. Other *in vivo* CBCT studies are recommended on all teeth groups in different populations with a large sample, adding to the present ones, which could support the global tendency that is mentioned in the hypothesis or prove that differences are only on specific group(s) of teeth.

Bilateral Symmetry:

In the present *in vivo* study, CBCT was used to evaluate bilateral symmetry and asymmetry of number of roots, number of canals and canal configurations of all permanent dentition in the same individuals. All variables were analyzed independently from each other, so regardless of the number of roots per tooth, number of canals and canals configurations were evaluated separately to establish a comprehensively conclusive study. Comparing our findings with the results of the previously published studies, some researchers combined the number of roots with number of canals as one variable and others combined number of roots with canal configurations, while other ones analyzed number of roots, number of canals and canal configurations separately similar to our study.

In maxillary teeth groups, in a Saudi study on maxillary premolars, the bilateral symmetries in number of roots and canal configurations were 91.2% and 85.3%, for first and second maxillary premolars, respectively, which is close to our findings. (118) A study in an Indian population on maxillary premolars that analyzed the symmetry of number of roots and canals together reported 81.5% for both maxillary premolar groups. (125) The findings of this study are below the range of our results. In maxillary molar teeth groups, studies in an Indian (125) and a White (126) populations on maxillary first molar groups showed 77.5% and 71.1% bilateral symmetry, respectively. While second molar groups showed 70.8% and 79.6% bilateral symmetry, respectively. The sample size of the second study was small. However, both studies' results showed less frequency of bilateral symmetry than our findings.

In mandibular teeth groups, a study from China (121) These findings are close to our results. In a Turkish study, Kayaoglu et al. reported that the total bilateral symmetry of number of roots and number of canals for mandibular central incisors, lateral incisors and canines groups ranged from 96% to 100% and from 90% to 95%, respectively, which are also similar to our findings.

(11) Two CBCT studies with large sample sizes analyzed the bilateral symmetry of mandibular anterior teeth with 2 canals. One of them reported the frequency to be 58.7% in central incisors, 76.1% in lateral incisors and 29.6% in canines in Chinese population while, the other study reported 45.0% for the central incisors, 29.0% for the lateral incisors, and 28.0% for the canines in a Turkish population. (123) The findings of these two studies are higher than ours where the frequency of bilateral symmetry of 2 canals was 21.9%, 23.5% and 4.9% for central incisors, lateral incisors and canine teeth groups, respectively. In agreement with our findings, a study among Saudi population on mandibular canines reported 97.7% of the teeth showed symmetrical number of roots and canal configuration. (120)

Mandibular first premolars group showed 81.3% symmetrical root and root canal system between the right and left side in a Taiwanese population. (124) Whereas Felsypremila et al. found the frequency of bilateral symmetry of number of roots and number of canals was 96.1 % in mandibular first premolars group and 98.3% mandibular second premolars group in an Indian population. (125) These results of mandibular premolars could be comparable to our findings. For mandibular first molars group, Mashyakhy et al. in a Saudi sub-population evaluated the bilateral symmetry and reported 100% symmetry in number of roots and 56.4% in canals configurations, where mesial roots showed an overall canal system symmetry in 54.1% while, in distal roots the overall symmetry was 47.6%. The current study showed similar result in regards number of roots (100%), but higher frequency in symmetry of number of canals (89.3%) and canals configurations in mesial (87.6%) and distal (82.6%) roots. Two other CBCT studies reported 78.6% and 70.6% bilateral symmetry in first molars groups, while in second molars groups showed 70.8% and 81% in regards to number of roots and root canals, respectively. (125,126) These two studies showed lower frequency of bilateral symmetry compared to our results. The results of the above-mentioned *in vivo* CBCT studies are inconclusive and fragmented showing a big range of differences compared to our study results.

The reasons could be related to many factors including; small number of studies only present on specific teeth groups, different sample size, different ethnicity and the way they calculated their results.

One interesting finding in the present study is that the maxillary and mandibular second premolar groups have almost similar percentages of bilateral symmetry in number of canals. This interrelation could be just a coincidence and further studies could be done to evaluate such similarity. Our study also showed that teeth groups with lower frequency of bilateral symmetry, consequently had higher percentage of bilateral asymmetry in morphology. These teeth groups are; maxillary first premolars groups in regards to number of roots, and maxillary second premolars and second molars groups in regards to number of canals and canal configurations.

In mandibular teeth groups; lateral incisors and premolars groups in number of canals, and for canal configuration; lateral incisor, premolars, distal roots of first molars and mesial roots of second molars groups. These findings are of high clinical significance as practitioner treating contralateral teeth in the same individual should be aware of such differences. Up to our best knowledge, this is the first study of its type, and the way we evaluated all variables could be followed for future comprehensive studies.

VI. CONCLUSIONS

Within the limitations of the present study, the following conclusions could be drawn:

Gender Differences:

- No significant differences between both genders in relation to number of roots.
- Significant differences with regard to number of canals were detected only in three groups out of 14 groups of teeth where females had lower number of canals.
- In relation to canal configuration, two groups of maxillary teeth and three groups of mandibular teeth showed statistically significant differences between both genders.

Bilateral Symmetry:

- Most tooth groups tend to have higher bilateral symmetry in regards to number of roots followed by number of canals and canal configurations.
- Tooth groups present with high frequency of asymmetry should be carefully evaluated before initiating a RCT for a better outcome.
- In vivo CBCT (large field of view) proved to be an appropriate tool in evaluating root morphology and symmetry of all groups of teeth.

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VIII. PUBLISHED- SUBMITTED- PRESENTED RESEARCH

-Published Articles:

1. Journal of Endodontics. Volume 45, Number 10, October 2019

Analysis of fused-rooted maxillary first and second molars with merged and C-shaped canal configurations: Prevalence, characteristics and correlations in a Saudi Arabian population.

Mohammed Mashyakhy, Hemant Ramesh Chourasia, Ahmad Jabali, Abdulmajeed Almutairi, and **Gianluca Gambarini**

2. Acta stomatoligica Croatica. 2019;53(3):231-246

Root and root canal morphology differences between genders: A comprehensive in-vivo CBCT study in a Saudi population.

Mohammed Mashyakhy and **Gianluca Gambarini**

3. Saudi Dental Journal, 2019 Oct; 31(4): 481–486

Anatomical variations and bilateral symmetry of roots and root canal system of mandibular first permanent molars in Saudi Arabian population utilizing cone- beam computed tomography.

Mohammed Mashyakhy, Hemant Ramesh Chourasia, Esam Halboub, Abeer Almashraqi, Yahia Khubrani, **Gianluca Gambarini**

4. Journal of Contemporary Dental Practice, 2018;19(9):1152-1156
   (NOT RELATED TO THE MAIN TOPIC OF THE PhD.)

Nonsurgical Management and 2-year Follow-up by means of Cone Beam Computed Tomography of an Invasive Cervical Resorption in a Molar: A Case Report.

Mohammed Mashyakhy, Hemant Chourasia, Essam Halboub, Rafael Roges and **Gianluca Gambarini**

-Accepted Articles:

1.Nigerian Journal of Clinical Practice

Title: C-shaped canal configuration in mandibular premolars and molars: prevalence, correlation and differences: An in vivo study using cone-beam computed tomography.

Authors: Mohammed Mashyakhy, Hemant Chourasia, Ahmad Jabali, Hashim Bajawi, Hassan Jamal, Luca Testarelli and **Gianluca Gambarini**

-Posters and oral presentation at conferences:

18th Biennial ESE Congress - Brussels, Belgium (14–16 September 2017)

1. Clinical Poster Presentation.
   Diagnosis, management and follow up of External Cervical Resorption (ECR) in a molar using CBCT
   Authors: Mohammed Mashyakhy, Mahmoud Almasrahi, Mohamed Arishi and **Gianluca Gambarini**

19th Biennial ESE Congress - Vienna, Austria (12–14 September 2019)

2. Original Scientific Poster Presentation:
   C-shaped canal configurations in mandibular posterior teeth: An In vivo cone-beam computed tomography study
   Authors: Mohammed Mashyakhy, Mahmoud Almasrahi, Mohamed Shibani, **Gianluca Gambarini**

3. Clinical Poster Presentation:
   The role of cone-beam computed tomography in detecting merged canals in fused-rooted maxillary second molars.

Authors: Mohammed Mashyakhy, Mahmoud Almasrahi, Mohamed Shibani, **Gianluca Gambarini**

4. General Poster Presentation:
   Bilateral symmetry of the roots and root canal system of permanent mandibular first molars in Saudi population: in vivo cone-beam computed tomography study.
   Authors: Gianluca Gambarini , , Mahmoud Almasrahi, Mohamed Shibani, Ahmad Almalwi and **Mohammed Mashyakhy**

5. Oral Presentation on a freely chosen subject:
   Invasive Cervical Resporption (ICR), the use of 3D technology in diagnosis and treatment planning.
   Authors: Mohammed Mashyakhy and **Gianluca Gambarini**

IX. APPENDICES

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Legends to figures

Figure 7: CBCT coronal sections of maxillary second premolars showing different canals configurations; contralateral premolars of the same patient (a & b), and right and left premolars of the same patient (c & d).

Figure 8: CBCT images of different coronal and axial sections of the same patient showing; a) mandibular right canine with one canal and Vertucci type I, b) left canine with 2 roots and 2 canals with type V Vertucci, and c) all mandibular teeth with bilateral symmetry in number of roots and number of canals except for right and left canines (arrows) which show asymmetry.

Tables

The sample:

Table 1: Screened, excluded, and evaluated maxillary and mandibular teeth

	Screened	Excluded	Evaluated
MAXILLARY	2782	192	2590
MANDIBULAR	2755	91	2664
TOTAL	5537	283	5254

Table 2: Screened, excluded, and evaluated maxillary teeth

	Screened	Excluded	Evaluated
Central incisors	411	27	384
Lateral incisors	401	15	386
Canines	409	25	384
1st Premolars	380	29	351
2nd Premolars	390	31	359
1st Molars	393	39	354
2nd Molars	398	26	372
Total	2782	192	2590

Table 3: Screened, excluded, and evaluated mandibular teeth

	Screened	Excluded	Evaluated
Central incisors	411	1	410
Lateral incisors	414	2	412
Canines	415	5	410
1st Premolars	398	1	397
2nd Premolars	391	12	379
1st Molars	336	46	290
2nd Molars	390	24	366
Total	2755	91	2664

IV.1. External anatomy and internal morphology:

IV.1.1. Maxillary teeth:

Central incisors

Table 4: Frequency of number of roots, number of canals, and Vertucci type among maxillary central incisors

	Frequency	Percent
Number of roots (N= 384)		
1 root	384	100.0
Number of canals (N= 384)		
1 canal	384	100.0
Vertucci types (N= 384)		
Type I	384	100.0

Lateral incisors

Table 5: Frequency of number of roots, number of canals, and Vertucci type among maxillary central incisors

	Frequency	Percent
Number of roots (N= 386)		
1 root	386	100.0
Number of canals (N= 386)		
1 canal	386	100.0
Vertucci types (N= 386)		
Type I	386	100.0

Canines

Table 6: Frequency of number of roots, number of canals, and Vertucci type among maxillary canines

	Frequency	Percent
Number of roots (N= 384)		
1 root	384	100.0
Number of canals (N= 384)		
1 canal	380	99.0
2 canals	4	1.0
Vertucci types (N= 384)		
Type I	380	99.0
Type III	4	1.0

First premolars

Table 7: Frequency of number of roots, number of canals, and Vertucci type among maxillary first premolars

		Frequency	Percent
Number of roots (N= 351)			
	1 root	143	40.7
	2 roots	202*†	57.5
	3 roots	6‡	1.7
Number of canals (N= 351)			
	1 canal	13	3.7
	2 canals	327	93.2
	3 canals	9*	2.6
	4 canals	2†‡	0.6
Vertucci types (N= 351)			
	Type I	13	3.7
	Type II	24	6.8
	Type III	27	7.7
	Type IV	224	63.8
	Type V	52	14.8
	Type VI	1	0.3
	Other	10*	2.8

* 3 teeth had 2 roots, 3 canals, and C-shape configuration; † 1 tooth had 2 roots and 4 canals
‡ 1 tooth had 3 roots and 4 canals

Second premolars

Table 8: Frequency of number of roots, number of canals, and Vertucci type among maxillary second premolars

		Frequency	Percent
Number of roots (N= 359)			
	1 root	316	88.0
	2 roots	43	12.0
Number of canals (N= 359)			
	1 canal	137	38.2
	2 canals	219	61.0
	3 canals	3*	0.8
Vertucci types (N= 359)			
	Type I	137	38.2
	Type II	39	10.9
	Type III	55	15.3
	Type IV	69	19.2
	Type V	44	12.3
	Type VI	4	1.1
	Type VII	8	2.2
	Other	3*	0.8

* 3 teeth had extra canals

First molars

Table 9: Frequency of number of roots, number of canals, and Vertucci type among maxillary first molars

		Frequency	Percent
Number of roots (N= 354)			
	3 roots	330	93.2
	Fused roots	24	6.8
Number of canals (N= 330)			
	3 canals	47	14.2
	4 canals	283	85.8
MB. Vertucci types (N= 330)			
	Type I	45	13.6
	Type II	116	35.2
	Type III	6	1.8
	Type IV	159	48.2
	Type V	2	0.6
	Type VI	2	0.6
DB. Vertucci types (N= 330)			
	Type I	330	100.0
P. Vertucci types (N= 330)			
	Type I	330	100.0

MB: Mesiobuccal; DB: Distobuccal; P: Palatal

Table 10: Frequency of number of roots, number of canals, and Vertucci type among maxillary first molars with fused-roots

		Frequency	Percent
Number of roots (N= 24)			
	1 root	6	25.0
	2 roots	18*	75.0
Number of canals (N= 22)			
	3 canals	7	31.8
	4 canals	15	68.2
MB. Vertucci types (N= 22)			
	Type I	7	31.8
	Type II	10	45.5
	Type IV	4	18.2
	Type V	1	4.5
DB. Vertucci types (N= 22)			
	Type I	22	100.0
P. Vertucci types (N= 22)			
	Type I	22	100.0

* 2 teeth had 2 roots, merged canals, and C- shape configuration; MB: Mesiobuccal; DB: Distobuccal; P: Palatal

Second molars

Table 11: Frequency of number of roots, number of canals, and Vertucci type among maxillary second molars

		Frequency	Percent
Number of roots (N= 372)			
	3 roots	292	78.5
	4 roots	2*	0.5
	Fused roots	78	21.0
Number of canals (N=292)			
	3 canals	98	33.6
	4 canals	194	66.4
MB. Vertucci type (N= 292)			
	Type I	96	32.9
	Type II	77	26.4
	Type III	8	2.7
	Type IV	95	32.5
	Type V	11	3.8
	Type VI	5	1.7
DB. Vertucci type (N= 292)			
	Type I	292	100.0
P. Vertucci type (N= 292)			
	Type I	292	100.0

*2 teeth had extra palatal roots; MB: Mesiobuccal; DB: Distobuccal; P: Palatal

Table 12: Frequency of number of roots, number of canals, and Vertucci type among maxillary second molars with fused-roots

		Frequency	Percent
Number of roots (N= 78)			
	1 root	24*	30.8
	2 roots	54†	69.2
Number of canals (N= 53)			
	3 canals	38	71.7
	4 canals	15	28.3
MB. Vertucci type (N= 53)			
	Type I	38	71.7
	Type II	5	9.4
	Type IV	9	17.0
	Type V	1	1.9
DB. Vertucci type (N= 53)			
	Type I	53	100.0
P. Vertucci type (N= 53)			
	Type I	53	100.0

*17 teeth had one root, merged canals, and C-shape configuration
†8 teeth had two roots, merged canals, and C-shape configuration
MB: Mesiobuccal; DB: Distobuccal; P: Palatal

IV.1.2. Mandibular teeth:

Central incisors

Table 13: Frequency of number of roots, number of canals, and Vertucci type among mandibular central incisors

		Frequency	Percent
Number of roots (N= 410)			
	1 root	410	100.0
Number of canals (N= 410)			
	1 canal	302	73.7
	2 canals	108	26.3
Vertucci types (N= 410)			
	Type I	302	73.7
	Type III	108	26.3

Lateral incisors

Table 14: Frequency of number of roots, number of canals, and Vertucci type among mandibular lateral incisors

		Frequency	Percent
Number of roots (N= 412)			
	1 root	410	99.5
	2 roots	2	0.5
Number of canals (N= 412)			
	1 canal	285	69.2
	2 canals	127	30.8
Vertucci types (N= 412)			
	Type I	285	69.2
	Type III	123	29.8
	Type V	4	1.0

Canines

Table 15: Frequency of number of roots, number of canals, and Vertucci type among mandibular canines

		Frequency	Percent
Number of roots (N= 410)			
	1 root	399	97.3
	2 roots	11	2.7
Number of canals (N= 410)			
	1 canal	372	90.7
	2 canals	38	9.3
Vertucci types (N= 410)			
	Type I	372	90.7
	Type III	25	6.1
	Type V	13	3.2

First premolars

Table 16: Frequency of number of roots, number of canals, and Vertucci type among mandibular first premolars

		Frequency	Percent
Number of roots (N= 397)			
	1 root	395*	99.5
	2 roots	2	0.5
Number of canals (N= 397)			
	1 canal	276	69.5
	2 canals	117†	29.5
	3 canals	4‡	1.0
Vertucci types (N= 397)			
	Type I	276	69.5
	Type III	25	6.3
	Type V	92§	23.2
	Type VII	1	0.3
	Other	3ﬁ	0.8

* 6 teeth had C-shape configuration; † 4 teeth had C-shape configuration; ‡ 2 teeth had C-shape configuration
§ 4 teeth had C-shape configuration; ﬁ 2 teeth had C-shape configuration

Second premolars

Table 17: Frequency of number of roots, number of canals, and Vertucci type among mandibular second premolars

		Frequency	Percent
Number of roots (N= 379)			
	1 root	379*	100.0
Number of canals (N= 379)			
	1 canal	367	96.8
	2 canals	8	2.1
	3 canals	4*	1.1
Vertucci types (N= 379)			
	Type I	367	96.8
	Type III	6	1.6
	Type V	3	0.8
	Other	3*	0.8

*3 teeth had 1 root, 3 canals, and C-shape configuration

First molars

Table 18: Frequency of number of roots, number of canals, and Vertucci type among mandibular first molars

		Frequency	Percent
Number of roots (N= 290)			
	2 roots	274	94.5
	3 roots	16*	5.5
Number of canals (N= 290)			
	2 canals	2	0.7
	3 canals	187	64.5
	4 canals	101*	34.8
M. Vertucci types (N= 290)			
	Type I	3	1.0
	Type II	105	36.2
	Type III	4	1.4
	Type IV	168	57.9
	Type V	10	3.4
D. Vertucci types (N= 290)			
	Type I	200	69.0
	Type II	9	3.1
	Type III	50	17.2
	Type IV	2	0.7
	Type V	29	10.0

*14 teeth had 3 roots and 4 canals; M: Mesial; D: Distal

Second molars

Table 19: Frequency of number of roots, number of canals, and Vertucci type among mandibular second molars

		Frequency	Percent
Number of roots (N= 366)			
	1 root	31*†	8.5
	2 roots	328	89.6
	3 roots	7‡	1.9
Number of canals (N= 337)			
	2 canals	23	6.8
	3 canals	294	87.2
	4 canals	20‡	5.9
M Vertucci type (N= 337)			
	Type I	21	6.2
	Type II	86	25.5
	Type III	54	16.0
	Type IV	133	39.5
	Type V	43	12.8
D Vertucci type (N= 337)			
	Type I	322	95.5
	Type II	3	0.9
	Type III	3	0.9
	Type V	9	2.7

* 2 teeth had fused roots without C-shape; † 29 teeth had fused roots with C-shape
‡ 7 teeth had 3 roots and 4 canals

IV.2. Gender differences:

IV.2.1. Maxillary and mandibular teeth:

Table 20: Distribution of maxillary teeth, mandibular teeth, and all maxillary and mandibular teeth together among both genders according to number of roots and number of canals

	Maxillary Teeth				Mandibular Teeth				ALL Teeth			
	M	**F**	**Total**	***P***	**M**	**F**	**Total**	***P***	**M**	**F**	**Total**	***P***
Number of roots												
1 root	777 (64.4)	836 (65.3)	1613 (64.9)	0.315	962 (74.5)	1033 (76.9)	1995 (75.7)	0.100	1739 (69.6)	1869 (71.2)	3608 (70.5)	0.064
2 roots	130 (10.8)	115 (9.0)	245 (9.9)		321 (24.5)	296 (22.0)	617 (23.4)		451 (18.1)	411 (15.7)	862 (16.8)	
3 roots	299 (24.8)	329 (25.7)	628 (25.3)		8 (0.6)	15 (1.1)	23 (0.9)		307 (12.3)	344 (13.1)	651 (12.7)	
Total	1206 (48.5)	1280 (51.5)	2486 (100.0)		1291 (49.0)	1344 (51.0)	2635 (100.0)		2497 (48.8)	2624 (51.2)	5121 (100.0)	
Number of canals												
1 canal	621 (51.5)	679 (53.0)	1300 (52.3)	**0.014***	751 (58.2)	851 (63.3)	1602 (60.8)	0.050	1372 (54.9)	1530 (58.3)	2902 (56.7)	0.082
2 canals	283 (23.5)	268 (20.9)	551 (22.2)		220 (17.0)	203 (15.1)	423 (16.1)		503 (20.1)	471 (17.9)	974 (19.0)	
3 canals	59 (4.9)	98 (7.7)	157 (6.3)		260 (20.1)	229 (17.0)	489 (18.6)		319 (12.8)	327 (12.5)	646 (12.6)	
4 canals	243 (20.1)	235 (18.4)	478 (19.2)		60 (4.6)	61 (4.5)	121 (4.6)		303 (12.1)	296 (11.3)	599 (11.7)	
Total	1206 (48.5)	1280 (51.5)	2486 (100.0)		1291 (49.0)	1344 (51.0)	2635 (100.0)		2497 (48.8)	2624 (51.2)	5121 (100.0)	

* Significant at *P*< 0.05

Table 21: Distribution of maxillary teeth, mandibular teeth, and all maxillary and mandibular teeth together among both genders according to canal configuration

	Maxillary teeth				Mandibular teeth											
	All teeth†				Anterior teeth and Premolars				Molars (1st and 2nd molars)							
									Mesial roots				Distal roots			
	M	F	Total	P	M	F	Total	P	M	F	Total	P	M	F	Total	P
Vertucci types																
Type I	672 (55.7)	771 (60.2)	1443 (58.0)	**<0.001***	751 (77.7)	851 (81.7)	1602 (79.8)	**0.016***	10 (3.1)	14 (4.6)	24 (3.8)	0.205	267 (82.4)	255 (84.2)	522 (83.3)	**<0.001***
Type II	132 (10.9)	122 (9.5)	254 (10.2)		0 (0.0)	0 (0.0)	0 (0.0)		89 (27.5)	102 (33.7)	191 (30.5)		1 (0.3)	11 (3.6)	12 (1.9)	
Type III	39 (3.2)	61 (4.8)	100 (4.0)		163 (16.9)	124 (11.9)	287 (14.3)		29 (9.0)	29 (9.6)	58 (9.3)		27 (8.3)	26 (8.6)	53 (8.5)	
Type IV	302 (25.0)	245 (19.1)	547 (22.0)		0 (0.0)	0 (0.0)	0 (0.0)		170 (52.5)	131 (43.2)	301 (48.0)		0 (0.0)	2 (0.7)	2 (0.3)	
Type V	40 (3.3)	69 (5.4)	109 (4.4)		49 (5.1)	63 (6.1)	112 (5.6)		26 (8.0)	27 (8.9)	53 (8.5)		29 (9.0)	9 (3.0)	38 (6.1)	
Type VI	9 (0.7)	3 (0.2)	12 (0.5)		0 (0.0)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Type VII	5 (0.4)	3 (0.2)	8 (0.3)		0 (0.0)	1 (0.1)	1 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Others	7 (0.6)	6 (0.5)	13 (0.5)		4 (0.4)	2 (0.2)	6 (0.3)		0 (0.0)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Total	1206 (48.5)	1280 (51.5)	2486 (100.0)		967 (48.2)	1041 (51.8)	2008 (100.0)		324 (51.7)	303 (48.3)	627 (100.0)		324 (51.7)	303 (48.3)	627 (100.0)	

* Significant at *P*< 0.05; † Only mesiobuccal roots of maxillary teeth were included in the analysis

IV.2.2. Maxillary teeth:

Central incisors

Table 22: Comparison of maxillary central incisors between males and females in relation to the study variables

	Male	Female	Total	P
Number of roots (N= 384)				
1 root	184 (47.9)	200 (52.1)	384 (100)	NC
Number of canals (N= 384)				
1 canal	184 (47.9)	200 (52.1)	384 (100)	NC
Vertucci types (N= 384)				
Type I	184 (47.9)	200 (52.1)	384 (100)	NC

Chi-Squared test was used; NC: Not computed

Lateral incisors

Table 23: Comparison of maxillary lateral incisors between males and females in relation to the study variables

	Male	Female	Total	P
Number of roots (N= 386)				
1 root	184 (48.2)	200 (51.8)	386 (100)	NC
Number of canals (N= 386)				
1 canal	184 (48.2)	200 (51.8)	386 (100)	NC
Vertucci types (N= 386)				
Type I	184 (48.2)	200 (51.8)	386 (100)	NC

Chi-Squared test was used; NC: Not computed

Canines

Table 24: Comparison of maxillary canines between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 384)					
	1 root	184 (100.0)	200 (100.0)	384 (100.0)	NC
	Total	184 (0.48)	200 (0.52)	384 (100.0)	
Number of canals (N= 384)					
	1 canal	180 (97.8)	200 (100.0)	380 (99.0)	0.052
	2 canals	4 (2.2)	0 (0.0)	4 (1.0)	
	Total	184 (0.48)	200 (0.52)	384 (100.0)	
Vertucci types (N= 384)					
	Type I	180 (97.8)	200 (100.0)	380 (99.0)	0.052
	Type III	4 (2.2)	0 (0.0)	4 (1.0)	
	Total	184 (0.48)	200 (0.52)	384 (100.0)	

Chi-Squared test was used; NC: Not computed; *significant at $P< 0.05$

First premolars

Table 25: Comparison of maxillary first premolars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 351)					
	1 root	63 (36.0)	80 (45.5)	143 (40.7)	0.161
	2 roots	108 (61.7)	94 (53.4)	202 (57.5)	
	3 roots	4 (2.3)	2 (1.1)	6 (1.7)	
	Total	175 (49.9)	176 (50.1)	351 (100.0)	
Number of canals (N= 351)					
	1 canal	9 (5.1)	4 (2.3)	13 (3.7)	0.152
	2 canals	158 (90.3)	169 (96.0)	327 (93.2)	
	3 canals	6 (3.4)	3 (1.7)	9 (2.6)	
	4 canals	2 (1.1)	0 (0.0)	2 (0.6)	
	Total	175 (49.9)	176 (50.1)	351 (100.0)	
Vertucci types (N= 351)					
	Type I	9 (5.1)	4 (2.3)	13 (3.7)	**<0.001***
	Type II	18 (10.3)	6 (3.4)	24 (6.8)	
	Type III	7 (4.0)	20 (11.4)	27 (7.7)	
	Type IV	119 (68.0)	105 (59.7)	224 (63.8)	
	Type V	15 (8.6)	37 (21.0)	52 (14.8)	
	Type VI	0 (0.0)	1 (0.6)	1 (0.3)	
	Other	7 (4.0)	3 (1.7)	10 (2.8)	
	Total	175 (49.9)	176 (50.1)	351 (100.0)	

Chi-Squared test was used; *significant at $P< 0.05$

Second premolars

Table 26: Comparison of maxillary second premolars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 359)					
	1 root	160 (87.9)	156 (88.1)	316 (88.0)	1.000
	2 roots	22 (12.1)	21 (11.9)	43 (12.0)	
	Total	182 (50.7)	177 (49.3)	359 (100.0)	
Number of canals (N= 359)					
	1 canal	62 (34.1)	75 (42.4)	137 (38.2)	**0.046***
	2 canals	120 (65.9)	99 (55.9)	219 (61.0)	
	3 canals	0 (0.0)	3 (1.7)	3 (0.8)	
	Total	182 (50.7)	177 (49.3)	359 (100.0)	
Vertucci types (N= 359)					
	Type I	62 (34.1)	75 (42.4)	137 (38.2)	0.064
	Type II	23 (12.6)	16 (9.0)	39 (10.9)	
	Type III	24 (13.2)	31 (17.5)	55 (15.3)	
	Type IV	41 (22.5)	28 (15.8)	69 (19.2)	
	Type V	23 (12.6)	21 (11.9)	44 (12.3)	
	Type VI	4 (2.2)	0 (0.0)	4 (1.1)	
	Type VII	5 (2.7)	3 (1.7)	8 (2.2)	
	Other	0 (0.0)	3 (1.7)	3 (0.8)	
	Total	182 (50.7)	177 (49.3)	359 (100.0)	

Chi-Squared test was used; *significant at $P< 0.05$

First molars

Table 27: Comparison of maxillary first molars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 330)					
	3 roots	151 (100.0)	179 (100.0)	330 (100.0)	NC
	Total	151 (45.76)	179 (54.24)	330 (100.0)	
Number of canals (N= 330)					
	3 canals	13 (8.6)	34 (19.0)	47 (14.2)	**0.007***
	4 canals	138 (91.4)	145 (81.0)	283 (85.8)	
	Total	151 (45.76)	179 (54.24)	330 (100.0)	
MB. Vertucci types (N= 330)					
	Type I	13 (8.6)	32 (17.9)	45 (13.6)	0.068
	Type II	54 (35.8)	62 (34.6)	116 (35.2)	
	Type III	3 (2.0)	3 (1.7)	6 (1.8)	
	Type IV	79 (52.3)	80 (44.7)	159 (48.2)	
	Type V	0 (0.0)	2 (1.1)	2 (0.6)	
	Type VI	2 (1.3)	0 (0.0)	2 (0.6)	
	Total	151 (45.76)	179 (54.24)	330 (100.0)	
DB. Vertucci types (N= 330)					
	Type I	151 (100.0)	179 (100.0)	330 (100.0)	NC
	Total	151 (45.76)	179 (54.24)	330 (100.0)	
P. Vertucci types (N= 330)					
	Type I	151 (100.0)	179 (100.0)	330 (100.0)	NC
	Total	151 (45.76)	179 (54.24)	330 (100.0)	

Chi-Squared test was used; NC: Not computed; *significant at $P < 0.05$
MB: Mesiobuccal; DB: Distobuccal; P: Palatal

Second molars

Table 28: Comparison of maxillary second molars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 392)					
	3 roots	144 (100.0)	148 (100.0)	292 (100.0)	NC
	Total	144 (0.49)	148 (0.51)	292 (100.0)	
Number of canals (N= 392)					
	3 canals	40 (27.8)	58 (39.2)	98 (33.6)	**0.047***
	4 canals	104 (72.2)	90 (60.8)	194 (66.4)	
	Total	144 (0.49)	148 (0.51)	292 (100.0)	
MB. Vertucci types (N= 392)					
	Type I	38 (26.4)	58 (39.2)	96 (32.9)	**<0.001***
	Type II	37 (25.7)	40 (27.0)	77 (26.4)	
	Type III	1 (0.7)	7 (4.7)	8 (2.7)	
	Type IV	63 (43.8)	32 (21.6)	95 (32.5)	
	Type V	2 (1.4)	9 (6.1)	11 (3.8)	
	Type VI	3 (2.1)	2 (1.4)	5 (1.7)	
	Total	144 (0.49)	148 (0.51)	292 (100.0)	
DB. Vertucci types (N= 392)					
	Type I	144 (100.0)	148 (100.0)	292 (100.0)	NC
	Total	144 (0.49)	148 (0.51)	292 (100.0)	
P. Vertucci types (N= 392)					
	Type I	144 (100.0)	148 (100.0)	292 (100.0)	NC
	Total	144 (0.49)	148 (0.51)	292 (100.0)	

Chi-Squared test was used; NC: Not computed; *significant at $P< 0.05$
MB: Mesiobuccal; DB: Distobuccal; P: Palatal

IV.1.2. Mandibular teeth:

Central incisors

Table 29: Comparison of mandibular central incisors between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 410)					
	1 root	196 (100)	214 (100)	410 (100)	NC
	Total	196 (47.8)	214 (52.2)	410 (100)	
Number of canals (N= 410)					
	1 canal	132 (67.3)	170 (79.4)	302 (73.7)	**0.007***
	2 canals	64 (32.7)	44 (20.6)	108 (26.3)	
	Total	196 (47.8)	214 (52.2)	410 (100)	
Vertucci type (N= 410)					
	Type I	132 (67.3)	170 (79.4)	302 (73.7)	**0.007***
	Type III	64 (32.7)	44 (20.6)	108 (26.3)	
	Total	196 (47.8)	214 (52.2)	410 (100)	

Chi-Squared test was used; NC: Not computed; *significant at *P*< 0.05

Lateral incisors

Table 30: Comparison of mandibular lateral incisors between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 412)					
	1 root	197 (99.5)	213 (99.5)	410 (99.5)	1.000
	2 roots	1 (0.5)	1 (0.5)	2 (0.5)	
	Total	198 (48.1)	214 (51.9)	412 (100.0)	
Number of canals (N= 412)					
	1 canal	133 (67.2)	152 (71.0)	285 (69.2)	0.455
	2 canals	65 (32.8)	62 (29.0)	127 (30.8)	
	Total	198 (48.1)	214 (51.9)	412 (100.0)	
Vertucci types (N= 412)					
	Type I	133 (67.2)	152 (71.0)	285 (69.2)	0.698
	Type III	63 (31.8)	60 (28.0)	123 (29.8)	
	Type V	2 (1.0)	2 (1.0)	4 (1.0)	
	Total	198 (48.1)	214 (51.9)	412 (100.0)	

Chi-Squared test was used; NC: Not computed; *significant at *P*< 0.05

Canines

Table 31: Comparison of mandibular canines between males and females in relation to the study variables

	Male	Female	Total	P
Number of roots (N= 410)				
1 root	195 (99.0)	204 (95.8)	399 (97.3)	0.064
2 roots	2 (1.0)	9 (4.2)	11 (2.7)	
Total	197 (48.0)	213 (52.0)	410 (100.0)	
Number of canals (N= 410)				
1 canal	184 (93.4)	188 (88.3)	372 (90.7)	0.088
2 canals	13 (6.6)	25 (11.7)	38 (9.3)	
Total	197 (48.0)	213 (52.0)	410 (100.0)	
Vertucci type (N= 410)				
Type I	184 (93.4)	188 (88.3)	372 (90.7)	**0.049***
Type III	11 (5.6)	14 (6.6)	25 (6.1)	
Type V	2 (1.0)	11 (5.2)	13 (3.2)	
Total	197 (48.0)	213 (52.0)	410 (100.0)	

Chi-Squared test was used; * significant at $P< 0.05$

First premolars

Table 32: Comparison of mandibular first premolars between males and females in relation to the study variables

	Male	Female	Total	P
Number of roots (N= 397)				
1 root	186 (98.9)	209 (100.0)	395 (99.5)	0.224
2 roots	2 (1.1)	0 (0.0)	2 (0.5)	
Total	188 (47.4)	209 (52.6)	397 (100.0)	
Number of canals (N= 397)				
1 canal	124 (66.0)	152 (72.7)	276 (69.5)	0.229
2 canals	61 (32.4)	56 (26.8)	117 (29.5)	
3 canals	3 (1.6)	1 (0.5)	4 (1.0)	
Total	188 (47.4)	209 (52.6)	397 (100.0)	
Vertucci types (N= 397)				
Type I	124 (66.0)	152 (72,7)	276 (69.5)	**0.012***
Type III	20 (10.6)	5 (2.4)	25 (6.3)	
Type V	42 (22.3)	50 (23.9)	92 (23.2)	
Type VII	0 (0.0)	1 (0.5)	1 (0.3)	
Other	2 (1.1)	1 (0.5)	3 (0.8)	
Total	188 (47.4)	209 (52.6)	397 (100.0)	

Chi-Squared test was used; * significant at $P< 0.05$

Second premolars

Table 33: Comparison of mandibular second premolars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 397)					
	1 root	188 (100.0)	191 (100.0)	379 (100.0)	NC
	Total	188 (49.6)	191 (50.4)	379 (100.0)	
Number of canals (N= 397)					
	1 canal	178 (94.7)	189 (99.0)	367 (96.8)	0.055
	2 canals	7 (3.7)	1 (0.5)	8 (2.1)	
	3 canals	3 (1.6)	1 (0.5)	4 (1.1)	
	Total	188 (49.6)	191 (50.4)	379 (100.0)	
Vertucci types (N= 397)					
	Type I	178 (94.7)	189 (99.0)	367 (96.8)	0.098
	Type III	5 (2.7)	1 (0.5)	6 (1.6)	
	Type V	3 (1.6)	0 (0.0)	3 (0.8)	
	Other	2 (1.1)	1 (0.5)	3 (0.8)	
	Total	188 (49.6)	191 (50.4)	379 (100.0)	

Chi-Squared test was used; NC: Not computed

First molars

Table 34: Comparison of mandibular first molars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 290)					
	2 roots	145 (96.0)	129 (92.8)	274 (94.5)	0.305
	3 roots	6 (4.0)	10 (7.2)	16 (5.5)	
	Total	151 (52.1)	139 (47.9)	290 (100.0)	
Number of canals (N= 290)					
	2 canals	1 (0.7)	1 (0.7)	2 (0.7)	0.987
	3 canals	98 (64.9)	89 (64.0)	187 (64.5)	
	4 canals	52 (34.4)	49 (35.3)	101 (34.8)	
	Total	151 (52.1)	139 (47.9)	290 (100.0)	
M. Vertucci types (N= 290)					
	Type I	2 (1.3)	1 (0.7)	3 (1.0)	0.471
	Type II	48 (31.8)	57 (41.0)	105 (36.2)	
	Type III	3 (2.0)	1 (0.7)	4 (1.4)	
	Type IV	93 (61.6)	75 (54.0)	168 (57.9)	
	Type V	5 (3.3)	5 (3.6)	10 (3.4)	
	Total	151 (52.1)	139 (47.9)	290 (100.0)	
D. Vertucci types (N= 290)					
	Type I	103 (68.2)	97 (69.8)	200 (69.0)	**0.005***
	Type II	1 (0.7)	8 (5.8)	9 (3.1)	
	Type III	25 (16.6)	25 (18.0)	50 (17.2)	
	Type IV	0 (0.0)	2 (1.4)	2 (0.7)	
	Type V	22 (14.6)	7 (5.0)	29 (10.0)	
	Total	151 (52.1)	139 (47.9)	290 (100.0)	

Chi-Squared test was used; M: Mesial; D: Distal; *significant at $P < 0.05$

Second molars

Table 35: Comparison of mandibular second molars between males and females in relation to the study variables

		Male	Female	Total	P
Number of roots (N= 337)					
	1 root	0 (0.0)	2 (1.2)	2 (0.6)	0.162
	2 roots	171 (98.8)	157 (95.7)	328 (97.3)	
	3 roots	2 (1.2)	5 (3.0)	7 (2.1)	
	Total	173 (51.3)	164 (48.7)	337 (100.0)	
Number of canals (N= 337)					
	2 canals	9 (5.2)	14 (8.5)	23 (6.8)	0.253
	3 canals	156 (90.2)	138 (84.1)	294 (87.2)	
	4 canals	8 (4.6)	12 (7.3)	20 (5.9)	
	Total	173 (51.3)	164 (48.7)	337 (100.0)	
M. Vertucci types (N= 337)					
	Type I	8 (4.6)	13 (7.9)	21 (6.2)	0.336
	Type II	41 (23.7)	45 (27.4)	86 (25.5)	
	Type III	26 (15.0)	28 (17.1)	54 (16.0)	
	Type IV	77 (44.5)	56 (34.1)	133 (39.5)	
	Type V	21 (12.1)	22 (13.4)	43 (12.8)	
	Total	173 (51.3)	164 (48.7)	337 (100.0)	
D. Vertucci types (N= 337)					
	Type I	164 (94.8)	158 (96.3)	322 (95.5)	0.112
	Type II	0 (0.0)	3 (1.8)	3 (0.9)	
	Type III	2 (1.2)	1 (0.6)	3 (0.9)	
	Type V	7 (4.0)	2 (1.2)	9 (2.7)	
	Total	173 (51.3)	164 (48.7)	337 (100.0)	

Chi-Squared test was used; M: Mesial; D: Distal

IV.3. Bilateral symmetry:

IV.3.1. Maxillary teeth:

Table 36: Total bilateral symmetry of maxillary teeth according to number of roots, and number of canals

	Centrals		**Laterals**		**Canines**		**1st Premolars**		**2nd Premolars**		**1st molars**		**2nd molars**	
	Symm	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
Number of roots														
1 root	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**183 (100.0)**	0 (0.0)	**53 (32.8)**	24 (14.8)	**140 (84.8)**	11 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**83 (51.2)**	24 (14.8)	**14 (8.6)**	11 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.2)**	0 (0.0)	0 (0.0)	0 (0.0)	**143 (100)**	0 (0.0)	**127 (100.0)**	0 (0.0)
Number of canals														
1 canal	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**180 (98.4)**	2 (1.1)	**2 (1.2)**	**8 (4.9)**	**49 (29.7)**	27 (16.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.1)**	**147 (90.8)**	10 (6.2)	**87 (52.7)**	28 (17.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.2)	**2 (1.2)**	1 (0.6)	**1 (0.6)**	**18 (12.6)**	6 (4.2)	**30 (23.7)**	24 (18.8)
4 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.2)**	0 (0.0)	0 (0.0)	**119 (83.2)**	6 (4.2)	**73 (57.5)**	24 (18.8)

Bold numbers refer to the more frequent values; Mesiobuccal roots of 1st and 2nd molars were the only roots included in analysis

Table 37: Total bilateral symmetry of maxillary teeth according to canal configuration

	Centrals		**Laterals**		**Canines**		**1st Premolars**		**2nd Premolars**		**1st molars**		**2nd molars**	
	Symm	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
Vertucci types														
Type I	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**180 (98.4)**	2 (1.1)	**2 (1.2)**	**8 (4.9)**	**49 (29.7)**	27 (16.2)	**17 (11.9)**	6 (4.2)	**30 (23.7)**	22 (17.3)
Type II	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.1)**	8 (4.9)	**8 (4.9)**	11 (6.7)	**12 (7.2)**	**40 (28.0)**	21 (14.7)	21 (16.5)	**25 (19.7)**
Type III	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (4.9)	**10 (6.2)**	15 (9.1)	**24 (14.4)**	0 (0.0)	**3 (2.1)**	1 (0.8)	**5 (3.9)**
Type IV	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**96 (59.3)**	15 (9.3)	**24 (14.5)**	14 (8.4)	**59 (41.3)**	20 (14.0)	**32 (25.2)**	18 (14.2)
Type V	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**18 (11.1)**	11 (6.9)	11 (6.7)	**19 (11.4)**	0 (0.0)	**2 (1.4)**	2 (1.6)	**7 (5.5)**
Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.6)**	1 (0.6)	**2 (1.2)**	0 (0.0)	**2 (1.4)**	**2 (1.6)**	1 (0.8)
Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**7 (4.8)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**3 (1.9)**	1 (0.6)	1 (0.6)	**1 (0.6)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values; Mesiobuccal roots of 1st and 2nd molars were the only roots included in analysis

Central incisors

Table 38: Bilateral symmetry of maxillary central incisors among participants in relation to the study variables

		Left Roots#	**P**
		1 root	
Right Roots#	1 root	**185 (100.0)**	NC
		Left Canals#	**P**
		1 canal	
Right Canals#	1 canal	**185 (100.0)**	NC
		Left Vertucci	**P**
		Type I	
Right Vertucci	Type I	**185 (100.0)**	NC

Cohen's Kappa test was used; NC: Not computed

Lateral incisors

Table 39: Bilateral symmetry of maxillary lateral incisors among participants in relation to the study variables

		Left Roots#	**P**
		1 root	
Right Roots#	1 root	**184 (100.0)**	NC
		Left Canals#	**P**
		1 canal	
Right Canals#	1 canal	**184 (100.0)**	NC
		Left Vertucci	**P**
		Type I	
Right Vertucci	Type I	**184 (100.0)**	NC

Cohen's Kappa test was used; NC: Not computed

Canines

Table 40: Bilateral symmetry of maxillary canines among participants in relation to the study variables

		Left Roots#		**P**
		1 root		
Right Roots#	1 root	**183 (100.0)**		NC
		Left Canals#		**P**
		1 canal	2 canals	
Right Canals#	1 canal	**180 (98.4)**	2 (1.1)	**<0.001***
	2 canals	0 (0.0)	**1 (0.5)**	
		Left Vertucci		**P**
		Type I	Type III	
Right Vertucci	Type I	**180 (98.4)**	2 (1.1)	**<0.001***
	Type III	0 (0.0)	**1 (0.5)**	

Cohen's Kappa test was used; NC: Not computed; *significant at $P< 0.05$

First premolars

Table 41: Bilateral symmetry of maxillary first premolars among participants in relation to the study variables

		Left Roots#			P
		1 root	2 roots	3 roots	
Right Roots#	1 root	**53 (32.8)**	12 (7.4)	0 (0.0)	**<0.001***
	2 roots	12 (7.4)	**83 (51.2)**	0 (0.0)	
	3 roots	0 (0.0)	0 (0.0)	**2 (1.2)**	

		Left Canals#			P
		1 canal	2 canals	3 canals	
Right Canals#	1 canal	**2 (1.2)**	5 (3.1)	0 (0.0)	**<0.001***
	2 canals	3 (1.9)	**147 (90.8)**	0 (0.0)	
	3 canals	0 (0.0)	1 (0.6)	**2 (1.2)**	
	4 canals	0 (0.0)	1 (0.6)	1 (0.6)	

		Left Vertucci						P
		Type I	Type II	Type III	Type IV	Type V	Other	
Right Vertucci	Type I	**2 (1.2)**	0 (0.0)	1 (0.6)	1 (0.6)	3 (1.9)	0 (0.0)	**<0.001***
	Type II	0 (0.0)	**8 (4.9)**	0 (0.0)	3 (1.9)	0 (0.0)	0 (0.0)	
	Type III	2 (1.2)	1 (0.6)	**8 (4.9)**	0 (0.0)	2 (1.2)	0 (0.0)	
	Type IV	1 (0.6)	4 (2.5)	1 (0.6)	**96 (59.3)**	0 (0.0)	0 (0.0)	
	Type V	0 (0.0)	0 (0.0)	3 (1.9)	3 (1.9)	**18 (11.1)**	0 (0.0)	
	Type VI	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	
	Other	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	**3 (1.9)**	

Cohen's Kappa test was used; *significant at *P*< 0.05

Second premolars

Table 42: Bilateral symmetry of maxillary second premolars among participants in relation to the study variables

		Left Roots#		P
		1 root	2 roots	
Right Roots#	1 root	**140 (84.8)**	6 (3.6)	**<0.001***
	2 roots	5 (3.0)	**14 (8.6)**	

		Left Canals#			P
		1 canal	2 canals	3 canals	
Right Canals#	1 canal	**49 (29.7)**	16 (9.7)	0 (0.0)	**<0.001***
	2 canals	11 (6.7)	**87 (52.7)**	0 (0.0)	
	3 canals	0 (0.0)	1 (0.6)	**1 (0.6)**	

		Left Vertucci								P
		Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Other	
Right Vertucci	Type I	**49 (29.7)**	2 (1.2)	8 (4.8)	1 (0.6)	5 (3.0)	0 (0.0)	0 (0.0)	0 (0.0)	**<0.001***
	Type II	0 (0.0)	**11 (6.7)**	2 (1.2)	2 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	Type III	5 (3.0)	0 (0.0)	**15 (9.1)**	2 (1.2)	4 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)	
	Type IV	0 (0.0)	3 (1.8)	2 (1.2)	**24 (14.5)**	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	
	Type V	5 (3.0)	0 (0.0)	1 (0.6)	1 (0.6)	**11 (6.7)**	0 (0.0)	3 (1.8)	0 (0.0)	
	Type VI	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.6)**	0 (0.0)	0 (0.0)	
	Type VII	1 (0.6)	2 (1.2)	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	Other	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.6)**	

Cohen's Kappa test was used; *significant at *P*< 0.05

First molars

Table 43: Bilateral symmetry of maxillary first molars among participants in relation to the study variables

		Left Roots#	P
		3 roots	
Right Roots#	3 roots	**143 (100)**	NC

		Left Canals#		P
		3 canals	4 canals	
Right Canals#	3 canals	**18 (12.6)**	4 (2.8)	**<0.001***
	4 canals	2 (1.4)	**119 (83.2)**	

		Left MB. Vertucci						P
		Type I	Type II	Type III	Type IV	Type V	Type VI	
Right MB. Vertucci	Type I	**17 (11.9)**	1 (0.7)	0 (0.0)	2 (1.4)	0 (0.0)	1 (0.7)	**<0.001***
	Type II	2 (1.4)	**40 (28.0)**	0 (0.0)	6 (4.2)	0 (0.0)	0 (0.0)	
	Type III	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	1 (0.7)	0 (0.0)	
	Type IV	0 (0.0)	10 (7.0)	1 (0.7)	**59 (41.3)**	0 (0.0)	1 (0.7)	
	Type V	0 (0.0)	1 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

		Left DB. Vertucci	P
		Type I	
Right DB. Vertucci	Type I	143 (100)	NC

		Left P. Vertucci	P
		Type I	
Right P. Vertucci	Type I	143 (100)	NC

Cohen's Kappa test was used; NC: Not computed; *significant at *P*< 0.05
MB: Mesiobuccal; DB: Distobuccal; P: Palatal

Second molars

Table 44: Bilateral symmetry of maxillary second molars among participants in relation to the study variables

		Left Roots#	P
		3 roots	
Right Roots#	3 roots	**127 (100.0)**	NC

		Left Canals#		P
		3 canals	4 canals	
Right Canals#	3 canals	**30 (23.7)**	12 (9.4)	**<0.001***
	4 canals	12 (9.4)	**73 (57.5)**	

		Left MB. Vertucci						P
		Type I	Type II	Type III	Type IV	Type V	Type VI	
Right MB. Vertucci	Type I	**30 (23.7)**	8 (6.3)	1 (0.8)	1 (0.8)	1 (0.8)	1 (0.8)	**<0.001***
	Type II	6 (4.7)	**21 (16.5)**	1 (0.8)	6 (4.7)	1 (0.8)	0 (0.0)	
	Type III	0 (0.0)	0 (0.0)	**1 (0.8)**	0 (0.0)	1 (0.8)	0 (0.0)	
	Type IV	3 (2.4)	3 (2.4)	2 (1.6)	**32 (25.2)**	1 (0.8)	0 (0.0)	
	Type V	1 (0.8)	0 (0.0)	0 (0.0)	2 (1.6)	**2 (1.6)**	0 (0.0)	
	Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.6)**	

		Left DB. Vertucci	P
		Type I	
Right DB. Vertucci	Type I	**127 (100.0)**	NC

		Left P. Vertucci	P
		Type I	
Right P. Vertucci	Type I	**127 (100.0)**	NC

Cohen's Kappa test was used; NC: Not computed; *significant at *P*< 0.05
MB: Mesiobuccal; DB: Distobuccal; P: Palatal

IV.3.2. Mandibular teeth:

Table 45: Total bilateral symmetry of mandibular teeth (anteriors and premolars) according to number of roots and number of canals

	Centrals		Laterals		Canines		1st Premolars		2nd Premolars	
	Symm	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
Number of roots										
1 root	**205 (100.0)**	0 (0.0)	**202 (99.0)**	2 (1.0)	**192 (95.1)**	9 (4.4)	**192 (99.0)**	2 (1.0)	**179 (100.0)**	0 (0.0)
2 roots	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.0)**	1 (0.5)	**9 (4.4)**	0 (0.0)	**2 (1.0)**	0 (0.0)	0 (0.0)
3 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Number of canals										
1 canal	**142 (69.3)**	18 (8.8)	**127 (62.3)**	29 (14.2)	**174 (86.1)**	18 (9.0)	**122 (62.9)**	24 (12.3)	**171 (95.5)**	5 (2.8)
2 canals	**45 (21.9)**	18 (8.8)	**48 (23.5)**	29 (14.2)	10 (4.9)	**18 (9.0)**	**46 (23.7)**	24 (12.3)	2 (1.1)	**4 (2.2)**
3 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.0)**	**1 (0.6)**	**1 (0.6)**
4 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values

Table 46: Total bilateral symmetry of mandibular teeth (anteriors and premolars) according to canal configuration

	Centrals		Laterals		Canines		1st Premolars		2nd Premolars	
	Symm	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
Vertucci types										
Type I	**142 (69.3)**	18 (8.8)	**127 (62.3)**	29 (14.2)	**174 (86.1)**	18 (8.8)	**122 (62.9)**	24 (12.4)	**171 (95.5)**	5 (2.9)
Type II	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type III	**45 (21.9)**	18 (8.8)	**46 (22.5)**	29 (14.2)	7 (3.5)	**11 (5.5)**	5 (2.6)	**14 (7.2)**	1 (0.6)	**4 (2.3)**
Type IV	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type V	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.0)**	1 (0.5)	**11 (5.5)**	**35 (18.0)**	22 (11.2)	0 (0.0)	**3 (1.8)**
Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**3 (1.5)**	0 (0.0)	**2 (1.2)**

Bold numbers refer to the more frequent values

Table 47: Bilateral symmetry of mandibular teeth (1st and 2nd molars) according to number of roots, number of canals, and canal configuration

		1st Molars				**2nd Molars**			
			Symm	**Asymm**			**Symm**	**Asymm**	
Number of roots									
	1 root		0 (0.0)	0 (0.0)			**1 (0.6)**	0 (0.0)	
	2 roots		**114 (94.2)**	1 (0.8)			**149 (96.2)**	3 (1.9)	
	3 roots		**6 (5.0)**	1 (0.8)			2 (1.3)	**3 (1.9)**	
Number of canals									
	1 canal		0 (0.0)	0 (0.0)			0 (0.0)	0 (0.0)	
	2 canals		0 (0.0)	**1 (0.8)**			6 (3.9)	**7 (4.5)**	
	3 canals		**73 (60.3)**	13 (10.7)			**131 (84.5)**	11 (7.0)	
	4 canals		**35 (28.9)**	12 (9.9)			**7 (4.5)**	4 (2.5)	
Vertucci types		**Mesial roots**		**Distal roots**		**Mesial roots**		**Distal roots**	
		Symm	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
	Type I	0 (0.0)	**2 (1.7)**	**77 (63.6)**	14 (11.6)	6 (3.9)	**6 (3.8)**	**147 (94.8)**	3 (1.9)
	Type II	**38 (31.4)**	12 (9.9)	2 (1.7)	**2 (1.7)**	**29 (18.7)**	19 (12.2)	**1 (0.6)**	0 (0.0)
	Type III	0 (0.0)	**3 (2.5)**	12 (9.9)	**18 (14.8)**	15 (9.7)	**19 (12.2)**	0 (0.0)	**2 (1.2)**
	Type IV	**64 (52.9)**	12 (9.9)	**1 (0.8)**	0 (0.0)	**53 (34.2)**	19 (12.2)	0 (0.0)	0 (0.0)
	Type V	**4 (3.3)**	1 (0.8)	8 (6.6)	**8 (6.6)**	12 (7.7)	**17 (10.9)**	3 (1.9)	**3 (1.9)**
	Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values

Central incisors

Table 48: Bilateral symmetry of mandibular central incisors among participants in relation to the study variables

		Left Roots#		**P**
		1 root		
Right Roots#	1 root	205 (100.0)		NC
		Left Canals#		**P**
		1 canal	2 canals	
Right Canals#	1 canal	**142 (69.3)**	12 (5.9)	**<0.001***
	2 canals	6 (2.9)	**45 (21.9)**	
		Left Vertucci		**P**
		Type I	Type III	
Right Vertucci	Type I	**142 (69.3)**	12 (5.9)	**<0.001***
	Type III	6 (2.9)	**45 (21.9)**	

Cohen's Kappa test was used; NC: Not computed; *significant at *P*< 0.05

Lateral incisors

Table 49: Bilateral symmetry of mandibular lateral incisors among participants in relation to the study variables

		Left Roots#			**P**
		1 root			
Right Roots#	1 root	**202 (99.0)**			NC
	2 roots	2 (1.0)			
		Left Canals#			**P**
		1 canal	2 canals		
Right Canals#	1 canal	**127 (62.3)**	16 (7.8)		**<0.001***
	2 canals	13 (6.4)	**48 (23.5)**		
		Left Vertucci			**P**
		Type I	Type III	Type V	
Right Vertucci	Type I	**127 (62.3)**	15 (7.3)	1 (0.5)	**<0.001***
	Type III	13 (6.4)	**46 (22.5)**	0 (0.0)	
	Type V	0 (0.0)	1 (0.5)	**1 (0.5)**	

Cohen's Kappa test was used; NC: Not computed; *significant at $P< 0.05$

Canines

Table 50: Bilateral symmetry of mandibular canines among participants in relation to the study variables

		Left Roots#			**P**
		1 root	2 roots		
Right Roots#	1 root	**192 (95.1)**	4 (1.9)		**0.023***
	2 roots	5 (2.5)	**1 (0.5)**		
		Left Canals#			**P**
		1 canal	2 canals		
Right Canals#	1 canal	**174 (86.1)**	9 (4.5)		**<0.001***
	2 canals	9 (4.5)	**10 (4.9)**		
		Left Vertucci			**P**
		Type I	Type III	Type V	
Right Vertucci	Type I	**174 (86.1)**	4 (1.9)	5 (2.5)	**<0.001***
	Type III	5 (2.5)	**7 (3.5)**	0 (0.0)	
	Type V	4 (1.9)	2 (1.1)	**1 (0.5)**	

Cohen's Kappa test was used; *significant at $P< 0.05$

First premolars

Table 51: Bilateral symmetry of mandibular first premolars among participants in relation to the study variables

		Left Roots#				
		1 root	2 roots	**P**		
Right Roots#	1 root	**192 (99.0)**	0 (0.0)	NC		
	2 roots	2 (1.0)	**0 (0.0)**			
		Left Canals#				
		1 canal	2 canals	3 canals	**P**	
Right Canals#	1 canal	**122 (62.9)**	9 (4.6)	0 (0.0)	**<0.001***	
	2 canals	14 (7.2)	**46 (23.7)**	1 (0.5)		
	3 canals	1 (0.5)	0 (0.0)	**1 (0.5)**		
		Left Vertucci				
		Type I	Type III	Type V	Other	**P**
Right Vertucci	Type I	**122 (62.9)**	4 (2.1)	5 (2.6)	0 (0.0)	**<0.001***
	Type III	4 (2.1)	**5 (2.6)**	3 (1.5)	0 (0.0)	
	Type V	9 (4.6)	3 (1.5)	**35 (18.0)**	1 (0.5)	
	Type VII	1 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	
	Other	1 (0.5)	0 (0.0)	1 (0.5)	**0 (0.0)**	

Cohen's Kappa test was used; *significant at *P*< 0.05

Second premolars

Table 52: Bilateral symmetry of mandibular second premolars among participants in relation to the study variables

		Left Roots#	**P**			
		1 root				
Right Roots#	1 root	**179 (100.0)**	NC			
		Left Canals#			**P**	
		1 canal	2 canals	3 canals		
Right Canals#	1 canal	**171 (95.5)**	1 (0.6)	1 (0.6)	**<0.001***	
	2 canals	3 (1.6)	**2 (1.1)**	0 (0.0)		
	3 canals	0 (0.0)	0 (0.0)	**1 (0.6)**		
		Left Vertucci				**P**
		Type I	Type III	Type V	Other	
Right Vertucci	Type I	**171 (95.5)**	1 (0.6)	0 (0.0)	1 (0.6)	**<0.001***
	Type III	2 (1.1)	**1 (0.6)**	0 (0.0)	0 (0.0)	
	Type V	1 (0.6)	1 (0.6)	0 (0.0)	0 (0.0)	
	Other	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	

Cohen's Kappa test was used; NC: Not computed; *significant at *P*< 0.05

First molars

Table 53: Bilateral symmetry of mandibular first molars among participants in relation to the study variables

		Left Roots#		
		2 roots	3 roots	**P**
Right Roots#	2 roots	**114 (94.2)**	0 (0.0)	**<0.001***
	3 roots	1 (0.8)	**6 (5.0)**	

		Left Canals#		
		3 canals	4 canals	**P**
Right Canals#	2 canals	1 (0.8)	0 (0.0)	**<0.001***
	3 canals	**73 (60.3)**	4 (3.3)	
	4 canals	8 (6.6)	**35 (28.9)**	

		Left M. Vertucci				
		Type II	Type III	Type IV	Type V	**P**
Right M. Vertucci	Type I	0 (0.0)	2 (1.7)	0 (0.0)	0 (0.0)	**<0.001***
	Type II	**38 (31.4)**	1 (0.8)	3 (2.5)	0 (0.0)	
	Type IV	8 (6.6)	0 (0.0)	**64 (52.9)**	1 (0.8)	
	Type V	0 (0.0)	0 (0.0)	0 (0.0)	**4 (3.3)**	

		Left D. Vertucci					
		Type I	Type II	Type III	Type IV	Type V	**P**
Right D. Vertucci	Type I	**77 (63.6)**	0 (0.0)	5 (4.1)	0 (0.0)	0 (0.0)	**<0.001***
	Type II	0 (0.0)	**2 (1.7)**	0 (0.0)	0 (0.0)	1 (0.8)	
	Type III	7 (5.8)	1 (0.8)	**12 (9.9)**	0 (0.0)	4 (3.3)	
	Type IV	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.8)**	0 (0.0)	
	Type V	2 (1.7)	0 (0.0)	1 (0.8)	0 (0.0)	**8 (6.6)**	

Cohen's Kappa test was used; M: Mesial; D: Distal; *significant at $P < 0.05$

Second molars

Table 54: Bilateral symmetry of mandibular second molars among participants in relation to the study variables

		Left Roots#			P
		1 root	2 roots	3 roots	
Right Roots#	1 root	1 (0.6)	0 (0.0)	0 (0.0)	**<0.001***
	2 roots	0 (0.0)	149 (96.2)	2 (1.3)	
	3 roots	0 (0.0)	1 (0.6)	2 (1.3)	

		Left Canals#			P
		2 canals	3 canals	4 canals	
Right Canals#	2 canals	6 (3.9)	2 (1.3)	0 (0.0)	**<0.001***
	3 canals	5 (3.2)	131 (84.5)	3 (1.9)	
	4 canals	0 (0.0)	1 (0.6)	7 (4.5)	

		Left M. Vertucci					P
		Type I	Type II	Type III	Type IV	Type V	
Right M. Vertucci	Type I	6 (3.9)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.6)	**<0.001***
	Type II	1 (0.6)	29 (18.7)	4 (2.6)	2 (1.3)	0 (0.0)	
	Type III	2 (1.3)	3 (1.9)	15 (9.7)	2 (1.3)	4 (2.6)	
	Type IV	0 (0.0)	8 (5.2)	1 (0.6)	53 (34.2)	2 (1.3)	
	Type V	2 (1.3)	1 (0.6)	3 (1.9)	4 (2.6)	12 (7.7)	

		Left D. Vertucci				P
		Type I	Type II	Type III	Type V	
Right D. Vertucci	Type I	147 (94.8)	0 (0.0)	1 (0.6)	2 (1.3)	**<0.001***
	Type II	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)	
	Type V	0 (0.0)	0 (0.0)	1 (0.6)	3 (1.9)	

Cohen's Kappa test was used; M: Mesial; D: Distal; *significant at $P < 0.05$

Figures

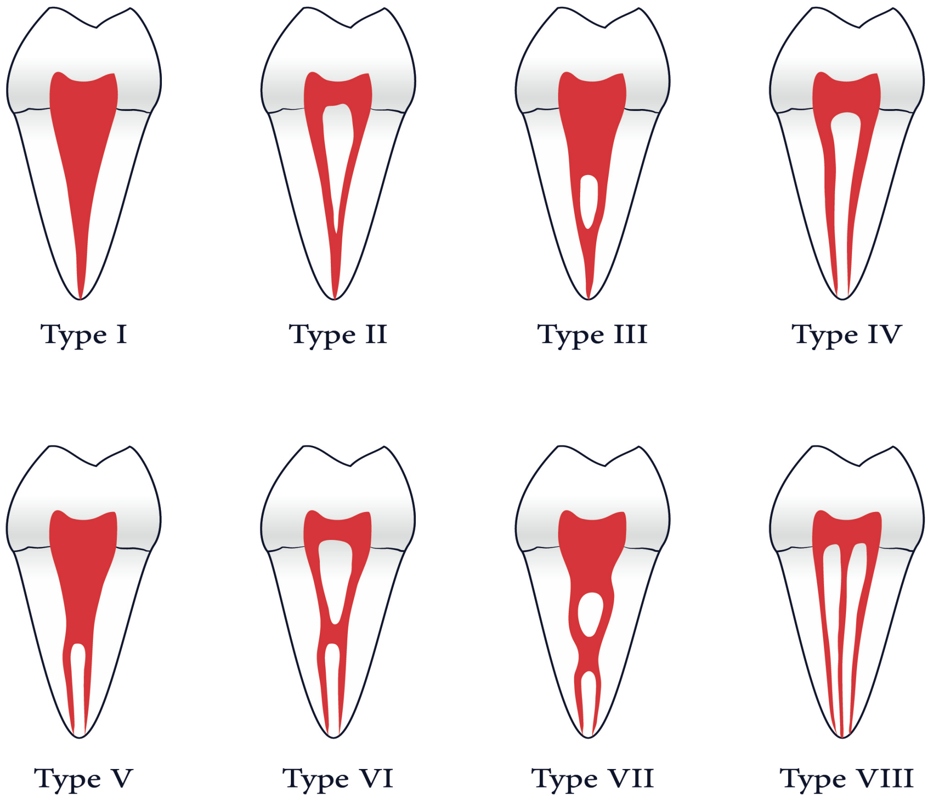

Figure 1: Types of root canal system configuration according to Vertucci classification

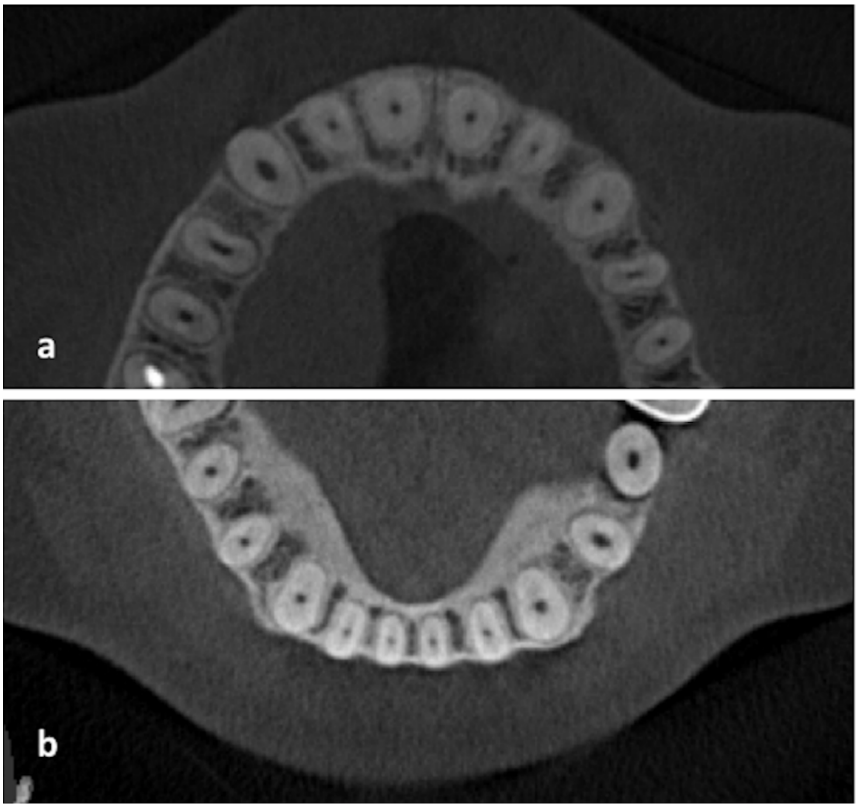

Figure 2: CBCT axial sections showing maxillary (a) and mandibular (b) anterior and premolar teeth with one canal and Vertucci Type I

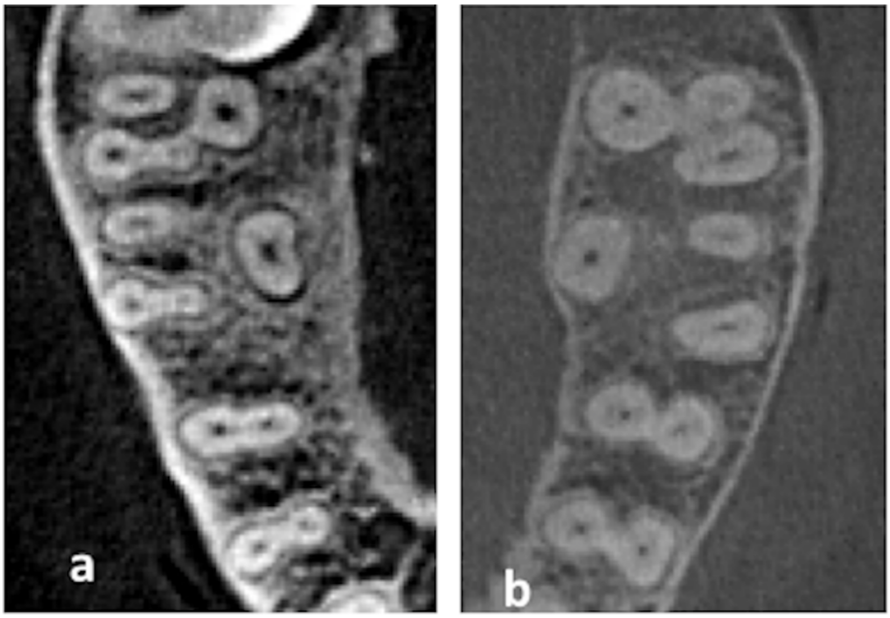

Figure 3: CBCT axial sections showing maxillary molars with 4 canals and premolars with 2 canals (a); and mandibular molars with 3 canals and premolars with 2 canals (b)

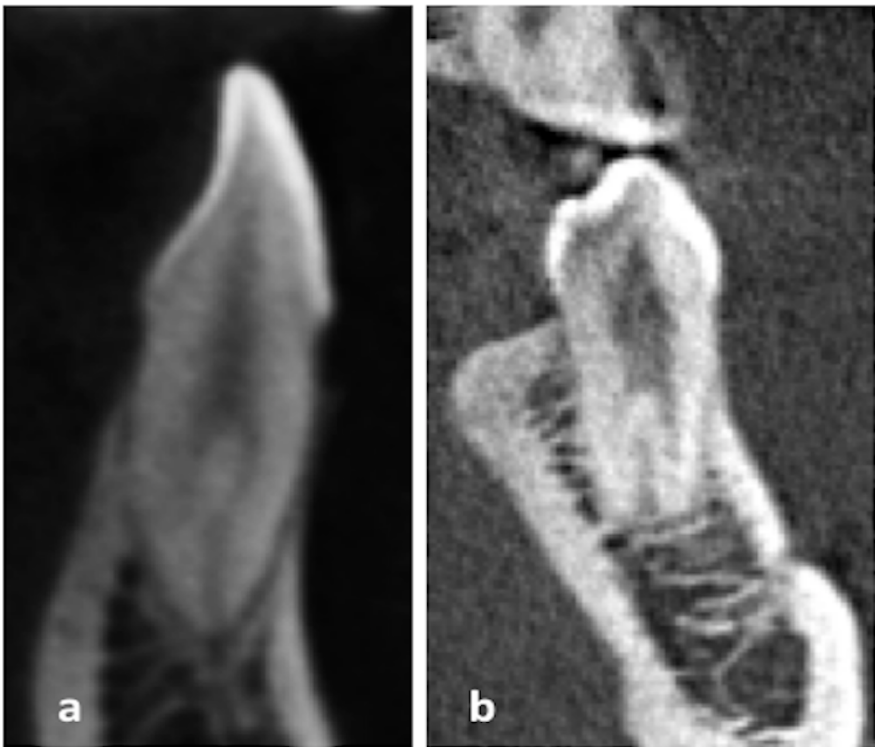

Figure 4: CBCT images showing sagittal sections (a) of mandibular central incisors with 2 canals and Vertucci type III; and coronal sections (b) of mandibular first premolar with 2 canals and Vertucci type V.

Figure 5: CBCT coronal sections showing different Vertucci types in maxillary premolars; Type II (a), Type IV (b), Type III (c), Type V (d).

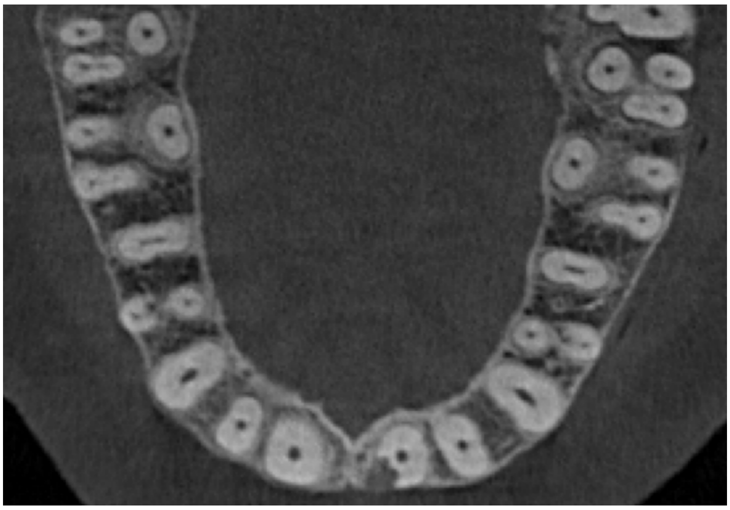

Figure 6: CBCT axial section showing all maxillary teeth with bilateral symmetry in number of roots and number of canals

Figure 7: CBCT coronal sections of maxillary second premolars showing different canals configurations; contralateral premolars of the same patient (a & b), and right and left premolars of the same patient (c & d).

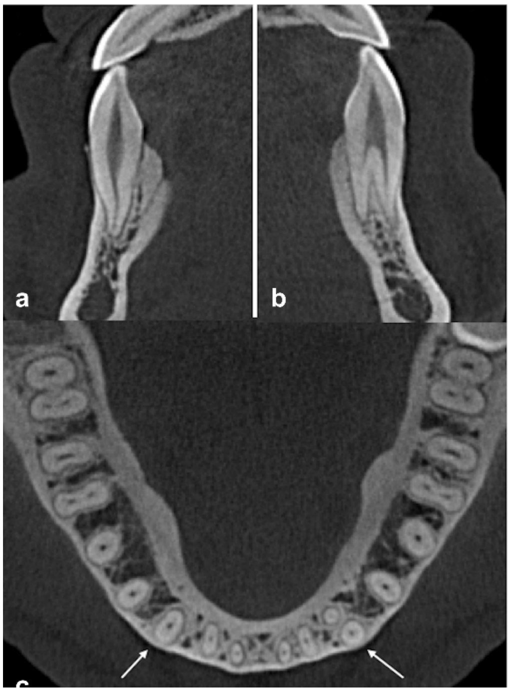

Figure 8: CBCT images of different coronal and axial sections of the same patient showing; a) mandibular right canine with one canal and Vertucci type I, b) left canine with 2 roots and 2 canals with type V Vertucci, and c) all mandibular teeth with bilateral symmetry in number of roots and number of canals except for right and left canines (arrows) which show asymmetry.

CLINICAL RESEARCH

Analysis of Fused Rooted Maxillary First and Second Molars with Merged and C-shaped Canal Configurations: Prevalence, Characteristics, and Correlations in a Saudi Arabian Population

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ABSTRACT

Introduction: The aims of this *in vivo* cone-beam computed tomographic (CBCT) study were to evaluate the prevalence, characteristics, and correlations between the fused rooted maxillary first and second molars as well as their consequent merged and C-shaped canals in a Saudi Arabian population. **Methods:** CBCT imaging of 726 maxillary first and second molars from 208 subjects of Saudi origin were evaluated in the present study. The prevalence of fused rooted maxillary molars, merged canals, C-shaped configurations, and correlations between the presence of fused rooted teeth between first and second molars were examined as the primary outcome. Differences by sex, location in the jaw, and bilateral symmetry (similarity between right- and left-side teeth in the same patient) were evaluated as the secondary outcome. The Z test was used for differences in the independent proportions, the chi-square test was used for differences between sex and locations, and the Cohen kappa test was used for bilateral symmetry. The kappa test was also used for intrarater reliability. A value of $P < .05$ was considered significant. **Results:** The prevalence of fused rooted maxillary first and second molars was 7% and 21%, respectively. Within fused rooted teeth, the presence of merged canals was 8.3% and 32.1%, whereas the prevalence of C-shaped canals was 8.3% and 5.1% in first and second maxillary molars, respectively. Among 57 subjects who had fused rooted maxillary molars, 19.3% showed a correlation between first and second molars. In fused rooted maxillary molars, 3.8% first molars and 13% second molars were bilaterally symmetrical. There were no statistically significant differences between sexes and right- and left-sided fused rooted maxillary molars, merged canals, or C-shaped canals.
Conclusions: Maxillary second molars presented more complex external and internal morphology compared with maxillary first molars, with an overall prevalence of 14% of fused rooted maxillary molars and 3.7% merged and 0.8% C-shaped canal configurations for all maxillary molars. The clinician should be aware of such challenges, and for a better treatment outcome, the use of CBCT imaging (small field of view) and an operative dental microscope can be considered when a preoperative periapical radiograph shows signs of fused rooted maxillary molars. *(J Endod 2019;45:1209–1218.)*

KEY WORDS

Cone-beam computed tomography; C shaped; fused rooted molars; merged canals; morphology

SIGNIFICANCE

Fused rooted maxillary molars with merged and C-shaped canals present a clinical challenge, and maxillary second molars exhibit more complex anatomy than maxillary first molars in terms of fused roots and merged and C-shaped canals.

The main objectives of root canal therapy (RCT) are to perform adequate biomechanical shaping, cleaning, and filling of the entire root canal system (RCS) in 3 dimensions, so the need for thorough

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ORIGINAL SCIENTIFIC PAPER
IZVORNI ZNANSTVENI RAD

Mohammed Mashyakhy[1], Gianluca Gambarini[2]

Root and Root Canal Morphology Differences Between Genders: A Comprehensive *in-vivo* CBCT Study in a Saudi Population

Razlike u broju i morofologiji korijena i korijenskih kanala među spolovima: sveobuhvatno istraživanje in-vivo primjenom CBCT-a na populaciji Saudijske Arabije

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Abstract

Objectives: To comprehensively explore the differences of all maxillary and mandibular permanent teeth in relation to number of roots, number of root canals, and root canal configuration between both genders in a Saudi Arabian population. **Methods:** This retrospective radiographic study comprised 208 subjects (48% males and 52% females) with a mean age 28.74±9.56 years. The CBCT images of the recruited subjects were evaluated for all permanent teeth. A careful examination was obtained by optimal visualization using all the software features. The data were analyzed using SPSS software program. Cohen's Kappa test was used for reliability and the Chi-squared test of association was used for the differences between both genders in relation to the study variables. A P-value < 0.05 was considered significant. **Results:** A total of 5254 maxillary and mandibular permanent teeth were evaluated. In relation to number of roots, there were no significant differences between both genders for all maxillary and mandibular teeth together (P= 0.064) as well as for maxillary and mandibular teeth separately (P= 0.315 and P= 0.100, respectively). A significant difference was found between males and females in relation to the number of canals of maxillary teeth (P= 0.014). For mandibular teeth, the significant level of difference was at the cut-off point (P= 0.050). For all maxillary and mandibular teeth together, the distribution among both genders was not significant (P= 0.082). The difference between both genders with regard to canal configuration of maxillary roots was highly statistically significant (P< 0.001). For mandibular teeth, the difference between males and females in relation canal configuration of anterior and premolar teeth was significant (P= 0.016) while, the difference was not significant when related to mesial roots of 1st and 2nd molars (P= 0.205). However, the difference was highly significant when related to distal roots of 1st and 2nd molars (P< 0.001). **Conclusion:** No significant differences between both genders in relation to number of roots were found. Regarding the number of canals, significant differences were found only in three groups out of 14 groups of teeth with females who had a smaller number of canals than males. For canal configuration, two groups of maxillary teeth and three groups of mandibular teeth showed statistically significant differences between both genders.

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Key words
Tooth root; Dental Pulp Cavity; Dental Anatomy

Introduction

Differences between genders regarding some anatomical variations (1), and the incidence and behavior of diseases are well documented in medicine (2–5) as well as in dentistry the differences between males and females regarding root morphology (6,7) and the association with some diseases were also reported (8,9). In the dental literature, many anatomical studies addressed different variations in root canal morphology according to ethnic background (10–18), while, scarce and inconclusive information are available regarding gender

Uvod

Razlike između spolova s obzirom na neke anatomske varijacije (1), zatim učestalost i tijek bolesti dobro su dokumentirani u općoj medicini (2 – 5), pa tako i u dentalnoj medicini postoje razlike između muškaraca i žena kad je riječ o morfologiji korijena zuba (6, 7) i o povezanosti s nekim bolestima (8, 9). U stomatološkoj literaturi autori mnogih anatomskih istraživanja bavili su se različitim varijacijama morfologije korijenskih kanala prema etničkoj pripadnosti (10 – 18), a dostupne su također rijetke i nedostatne informacije o utjecaju

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ORIGINAL ARTICLE

Anatomical variations and bilateral symmetry of roots and root canal system of mandibular first permanent molars in Saudi Arabian population utilizing cone- beam computed tomography

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KEYWORDS

Cone beam computed tomography;
Mandibular first molar;
Root canal;
Saudi Arabian

Abstract *Aim:* The aim of the study was to evaluate the anatomical variations of the roots and root canal system, and to determine the symmetry between right and left sides of mandibular first permanent molars in Saudi Arabian population using images derived from cone beam computed tomography (CBCT) scans.

Methods: The CBCT scans (with the following parameters: FOV 170 × 120 mm, 90 Kv, 5–8 mA, 17.5 s exposure time and 0.25 mm voxel size) were retrieved from the database and axial, coronal and sagittal sections of mandibular first molars were examined. The number of roots, canals and type of canal configuration based on Vertucci's classification were recorded. Bilateral symmetry between right and left side of the same individuals and differences between genders were investigated.

Results: Out of 174 mandibular first molars, 97.1% were two rooted and 2.9% were three rooted (distolingual root). In regards to the number of canals, 73% had three, 25.3% had four and 1.7% had two root canals. In teeth with four root canals, 90.9% of the extra canal was in the distal root, while 9.1% in the extra distolingual root. The most common canal configuration in mesial and distal root were type IV (64.9%) and type I (77%), respectively. Symmetrical analysis revealed 100% symmetry in number of roots and 56.4% in number of canals between right and left teeth in the same individual.

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CASE REPORT

Nonsurgical Management and 2-year Follow-up by means of Cone Beam Computed Tomography of an Invasive Cervical Resorption in a Molar

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ABSTRACT

Background: Invasive cervical resorption (ICR) is a relatively uncommon form of external tooth resorption, characterized by an invasive nature. It is usually painless and detection of lesions is often made incidentally. Three-dimensional imaging techniques, such as cone beam computed tomography (CBCT), are useful in the diagnosis and management of ICR as the true extent of the defect cannot always be estimated using conventional radiographs.

Aim: The aim of this article is to report on the successful treatment of ICR in mandibular first molar by nonsurgical approach and follow-up by means of CBCT.

Case report: An 18-year-old patient was referred with a complaint of unusual radiolucency in the mesial cervical area of tooth # 19 with unknown etiology. Cone beam computed tomography was performed to assess the extent of the lesion in three spatial levels and diagnosis of Heithersay class III ICR was made. This case presented with ICR (Heithersay class III) on tooth #19. Nonsurgical root canal treatment and removal of the lesion from the coronal access was performed; the resorptive defect was filled with dual-cure, self-adhesive, resin-modified glass ionomer cement (RMGIC); 6-month follow-up X-ray film showed no changes at the lesion site and tooth was asymptomatic; 1-year follow-up X-ray film showed slight mesial bone loss and a probing depth of 3 mm; finally, 2-year follow-up CBCT images showed no recurrence and no further bone destruction at the lesion site.

Conclusion: The intraoral radiographs revealed the resorptive changes in two dimensions; therefore, the actual extent and location of the lesions are not fully understood. On the contrary, CBCT is a very useful tool to achieve a proper diagnosis; it detects the extent of the defect more accurately and hence, improves the treatment outcomes of ICR.

Clinical significance: The ICR is usually seen as a late complication to traumatic injuries of the teeth; it is essential, therefore, that the patients who were exposed to situations that can damage the integrity of periodontal tissue need to have careful periodic recalls and X-ray examinations.

Keywords: Cone beam computed tomography, Invasive cervical resorption, Mandibular first molar, Nonsurgical root canal treatment.

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BACKGROUND

Invasive cervical resorption is a relatively uncommon form of external tooth resorption, characterized by an invasive nature. It starts below the epithelial attachment and subsequently invades the cementum, dentin, and, in late stage, reaches the pulp. The exact etiology of ICR is unknown; however, several potential predisposing factors have been suggested, which include history of orthodontic treatment, trauma, and intracoronal bleaching.[1,2] The condition is painless and detection of lesion is often made incidentally during routine examination

Diagnosis, management and follow up of External Cervical Resorption (ECR) in a molar using CBCT

SAPIENZA UNIVERSITÀ DI ROMA

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University of Rome (La Sapienza)

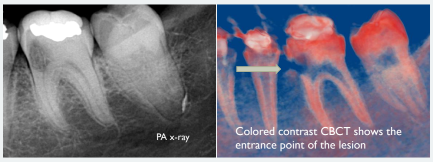
ESE 2017 BRUSSELS 14 TO 16 SEPTEMBER

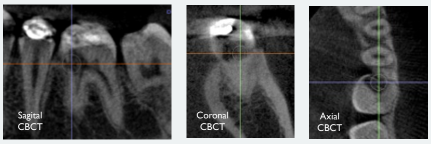
Introduction

ECR is a form of external root resorption characterized by an aggressive and invasive nature. Conventional radiographic techniques reveal limited information on the true extent and nature of the resorptive lesion. Recently, cone beam computed tomography (CBCT), which is an extraoral 3-dimensional imaging technique, has been used to assess ECR lesions. The position, depth in relation to the root canal, and ultimately the restorability of the tooth can be assessed objectively before any treatment is carried out. The diagnostic accuracy of CBCT is superior to intraoral radiographs in detecting the real extension of the resorptive lesion. Treatment, where indicated, should aim at the inactivation and removal of all resorbing tissues and the reconstitution of the resorptive defect by the placement of a suitable filing material.

Case Presentation

18 years old female patient presented for a consultation on mandibular first left molar with mesial - cervical radiolucency. Clinical, radiographic and CBCT were performed and a Diagnosis of a normal pulp with normal periapical tissue, and ECR CL II Heithersay classification was established.



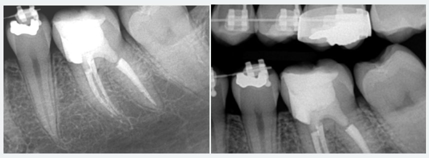


The treatment was decided after the extension of the lesion was determined by mean of CBCT and the prognosis was favorable for this tooth.

Treatment was performed under dental operative microscope and the material of choice was Resin modefied glass inonomer for the lesion side + conventional NSRCT.

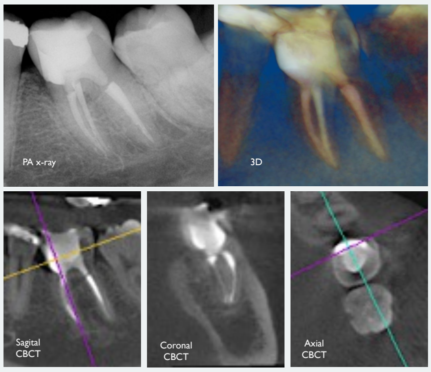
Case Presentation

Post operative x-ray



2 years recall x-ray and CBCT

After 2 years the patient presented for a maintenance visit, PAs and CBCT were taken as well as clinical examination. The tooth was asymptomatic and normal probing around the tooth, and CBCT showed no bone loss or recurrence of the lesion.



Discussion

It is well known that the effective dose of a CBCT scan is higher than PA radiography. CBCT scans should be kept "as low as reasonably achievable" . Therefore, the potential benefit of CBCT imaging should outweigh the potential risks and it is essential to use a high-resolution, small field of view CBCT scanner. The perfect diagnostic accuracy of CBCT in diagnosing resorption lesions is a result of the three-dimensional assessment of these resorption lesions. The sophisticated CBCT software allows the clinician to select the most favorable orthogonal views for each specific problem being assessed. In addition the thickness of each slice and the interval between each slice may be adjusted. These factors ultimately result in root resorption lesions being significantly more perceptible to the clinician compared with intraoral radiographs.

Conclusion

CBCT's superior diagnostic accuracy changed the way we look at diagnosis and prognosis of ECR lesion. It increases the likelihood of correct management of resorptive lesions compared with intraoral radiographs.

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The role of cone-beam computed tomography in detecting fused roots and merged canals in maxillary second molars

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Aim:

To use in vivo CBCT in diagnosing and planning for a proper management of a challenging internal morphology "merged canals" in fused-rooted maxillary second molars.

Introduction:

One of the anatomical variations present in maxillary second molars is root fusion, where the prevalence varies between different populations (1). A maxillary molar tooth is considered having root fusion when the ratio of the distance from the cementoenamel junction (CEJ) to the lower point of root furcation or root fusion and from the CEJ to the apex of the root is not less than 70% (9). Merged canals has a high prevalence in fused-rooted maxillary second molars which make the root canal treatment considerably difficult (1,2,3). CBCT is a valid and non-invasive method to evaluate such anatomical variations (1) and help in performing successful root canal treatment for better outcome.

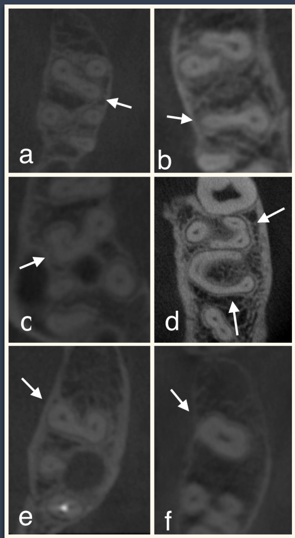

Fig1. Presents different type of fusions according to Zhang and Martins; a. type II, b. type III, c. type IV, d. arrow on the top type I, arrow in the bottom type V, e. type VI, f. type VII.

Methodology:

372 maxillary second molars from 208 patients (100 males and 108 females) with age ranging from 17 to 59 years were evaluated by CBCT.

Results:

The prevalence of fused-rooted second molars was 21%, 78 teeth. All 6 types of fusion defined by Zhang et al and extra types were found (Fig1). Out of the 78 teeth 25 representing (32.1%) have merged canals (Figs 2,3) as examples.

Frequency and percentage of different types of fusion among maxillary second molars

Fused teeth	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Others
78	9 (11.5)	39 (50.0)	5 (6.4)	10 (12.8)	3 (3.9)	7 (9.0)	4 (5.1)	1 (1.3)

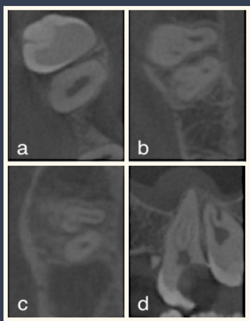

Fig2: Pre-operative CBCT sections of a maxillary second molar showing 3 canals joined apically as one canal; a,b and c are axial sections at coronal, middle and apical levels, d. sagittal section.

Fig3. Obturation of the fused-rooted maxillary second molars showing the 3 canals merged as one apically.

Discussion:

The prevalence of root fusion in maxillary second molars was 21%, in agreement with a current work in a Portuguese population using the same methodology and classification 25.2% (1). The prevalence of merged canals within fused roots was 32.1% in second molars. Interestingly, this finding is significantly lower than the prevalence in Portuguese population (62.3%) (1), and higher than the presence in Chinese one (10.6%) (2) Differences in definition of root fusion in the Chinese study compared to Martins et al (1) and our study, and consequently the presence of merged canals, could be the reason of the inconsistency. In addition to the ethnicity, where expected to find more complicated anatomy in Chinese populations but it the opposite.

Conclusion:

Maxillary second molars present with complex external and internal anatomy which make a challenge for practitioners. CBCT small field of view and operative surgical microscope are highly recommended to diagnose and/or treat maxillary molars with suspected fused roots for better prognosis.

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Bilateral symmetry of the roots and root canal system of permanent mandibular first molars in Saudi population: in vivo cone-beam computed tomography study

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Aim:

To identify the presence of bilateral symmetry of mandibular first molars in the same patients in regard to number of roots, canals and canal's configuration according to Vertucci classification.

Introduction:

Mandibular first molar is the first permanent tooth to erupt, most often affected by caries and frequently undergoes endodontic treatment. It is always presented with a complex internal morphology, especially in the mesial root (1). Recently, cone-beam computed tomography (CBCT) has been widely used with a wide range of applications in dental practice. Briefly, CBCT enables the clinicians to observe the three dimensions of the relevant area. Many studies have reported the usefulness of in vivo CBCT analysis in determining root canal anatomy (2). In fact, root morphology including number of canals can be visualized well in three dimensions allowing more thorough understanding of the true morphology of root canal systems (3).

Methodology:

A total of 174 mandibular first molars CBCT scans of (61 males and 37 females) with an age range between 18–50 years were collected, using (3D Accuitomo 170 machine (MORITA, Japan). The CBCT images were accessed and evaluated by two endodontists and any disagreement in assessment was resolved by consensus.

Results:

Out of 98 patients, 77 had both right and left first mandibular molars. With regard to number of roots; the right and left sides showed 100% symmetry. Three canals were the most prevalent in both right and left quadrant 51/58 (87.9%). The most common bilateral canal system configuration in mesial root was type IV representing 40/48 of cases (83.3%), and type I in distal root representing 55/61 of cases (90.2 %).

Discussion:

In the literature, few studies examined the symmetry between right and left mandibular molar teeth. Two studies using in vivo CBCT found symmetries in root numbers and canals morphology to be 70.6% in an Italian population (4) and 78.6% in Indian one (5). Regardless of the methodology used to evaluate the symmetries, our findings are within the main stream of both studies.

Conclusion:

There is a high possibility of having same external anatomy and internal morphology in right and left mandibular first molars in the same patient, so the clinician should be aware of the present anatomy. However, variations might happen so a CBCT small field of view scan is recommended when complicated anatomy is suspected in Periapical x-ray.

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C-shaped canal configurations in mandibular posterior teeth: An In vivo cone-beam computed tomography study

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• Aim:

To evaluate the prevalence and morphological differences of C-shaped canals, and to assess the relationship between the presence of C-shaped canal morphology within mandibular premolars and molars in the same individuals.

• Methodology:

Cone-bean computed tomography (CBCT) scans of 208 Saudi patients aged 17 to 60years including 1,433 mandibular posterior teeth (776 premolars and 657 molars) were evaluated for their external and internal morphology. Axial sections of the roots were acquired at three levels (coronal, middle, and apical) to identify and analyse root canal systems having a C-shaped canal configuration. The same Endodontist examined the CBCT images twice with a 4-week interval between viewings. For inter-rater reliability, two readings of 30% of the study sample were taken. Cohen's Kappa test revealed almost perfect agreement of measurement with a value of 0.85 and $p < 0.001$. The Z-test was used to determine the proportions in the independent groups. All statistical tests were performed at a significant level of $p < 0.05$.

• Results:

The prevalence of C-shaped canals in first premolars was 1.5%, 0.8% in second premolars, and 8% in second molars; the first molars had none. C-shaped type 2 canals were most prevalent in premolars and type 3 was most prevalent in the second molars. There was no correlation between the presence of C-shaped canals within premolars and molars in the same patients.

• Conclusions:

The prevalence of C-shaped canal configurations in mandibular second molars was significantly greater than in premolars. Teeth with C-shaped canals exhibited unpredictable morphology across the root length, making the use of a small field of view CBCT highly recommended when planning root canal treatment.

Invasive Cervical Resporption (ICR), the use of 3D technology in diagnosis and treatment planning

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Aim: The role of Micro computed tomography (Micro CT) and Cone-beam CT (CBCT) in understanding the extension of the lesion which help to predictably determine the prognosis of the treatment.

Presentation synopsis

ICR is a relatively uncommon form of external root resorption. Clinical, radiologic and pathologic features of invasive cervical resorption provide the basis for a clinical classification, which is of use both in treatment planning, and for comparative clinical research (Heithersay, 2004).

Treatment, where indicated, should aim at the inactivation of all resorbing tissue and the reconstitution of the resorptive defect either by the placement of a suitable filing material or by the use of biological systems (Heithersay 2004).

Despite the lack of knowledge in finding the exact etiological factors of ICR, practically detecting the extension of the lesion and treatment is vital.

Extension of the lesion, ability of the clinician to approach it and treat it helps to determine the prognosis. The lesion cannot be accurately detected with Periapical x-ray films (PA). Micro CT as an ex vivo technology allowed to understand precisely the way the lesion behaves. While, in vivo, advance in diagnostic tools, specially the use CBCT helped a lot in determining the prognosis of the treatment since its high accuracy shows the extension of the lesion.

Also, advance in material and armamentarium helped in performing the restorative procedure successfully and predictably.

Learning objectives:

1. Understanding the progress of the lesion ex vivo using Micro CT
2. Determine the extensions of the lesion in vivo using CBCT
3. Describe & Discuss the treatment and prognosis


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