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Root and Canal Morphology of Permanent Maxillary and Mandibular Incisor Teeth: A Systematic Review and Comparison with Saudi Arabian Population

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ABSTRACT

Here we summarize the original studies and case reports addressing the root and root canal morphology of permanent anterior teeth among the Saudi Arabian population, comparing findings to the international literature. The maxillary and mandibular central and lateral incisors are among the most likely teeth to require endodontic treatments, so their morphology should be considered for root canal treatment success. All related literature published between 1980 and 2020 in peer-reviewed journals were included in this review. A systematic literature exploration was carried-out using the PubMed, ScienceDirect, Scopus, Evidence-Based Dentistry Journal, and Dental Practice databases. The search terms used were: "root canal morphology", "root morphology", "case report for anterior maxillary and mandibular teeth", and "Saudi Arabian population". Twenty-nine original research articles were identified. Most of the studies used the cone beam computed tomography (CBCT) technique. A total of 29 original research studies were included in this review. In the Saudi-based original research, three studies addressed mandibular and one study maxillary teeth and were conducted in various cities. Twenty-nine clinical case reports are presented: among these, three were Saudi patients. When comparing Saudi data to data gathered in other populations, the findings were mostly consistent in canal and root configuration of maxillary and mandibular anterior teeth. New devices and technologies are clinically useful in the identification of morphological variations in permanent teeth. Greater attention should be given to detecting additional canals. Variation among canals of mandibular anterior and maxillary teeth should be considered for successful endodontic treatment.

KEY WORDS: CANAL CONFIGURATION, CASE REPORT, MANDIBULAR TEETH, MAXILLARY TEETH, ROOT CANAL SYSTEM, MORPHOLOGY, SAUDI ARABIA.

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INTRODUCTION

All root canal treatments (RCTs) rely on knowledge of the tooth morphology, and three-dimensional imaging of root canal systems (Castellucci., 2015; Bansal et al., 2018). It has been reported that the shape and number of roots and canals differ among genders and populations (Al-Fouzan et al., 2012; Mirhosseini et al., 2017; Saati et al., 2018; Mashyakhy., 2019; Valenti-Obino et al., 2019;

Baxter et al., 2020; Ghabbani et al., 2020). Therefore, it is important to be familiar with differences in the tooth outlines and characteristic features among ethnicities. Such knowledge can aid in the location and negotiation of canals (Arslan et al., 2015; Zhengyan et al., 2016; Verma et al., 2017; Martins et al., 2018; Martínez et al., 2018; Popovic et al., 2018; Shemesh et al.,2018).

A study classified the cross-sectional root canal configurations of mandibular teeth as round, oval, long oval, flattened, or irregular (Castellucci 2015). Whoever the majority of permanent of maxillary or mandibular incisors have one root and one canal; however, a small percentage may have a second canal, lateral canal, or apical deltas (Saati et al., 2018). The root canal systems of incisors do not consist of a single canal running uniformly from the orifice of the pulp champers to the apex. In fact, the root canal systems of incisors can be complex due to the splitting and reunion of the canals during its passage to the end of the roots (Vertucci., 1984; Saini et al., 1990; Altunsoy et al., 2014; Razumova et al., 2018; Mashyakhy and Gambarini., 2019; Pan et al., 2019).

The root canal systems of incisors open apically into the periodontium through apical and lateral foramens. During its passage, the root canal presents a variety of configurations, differing among tooth types, genders, and populations (Mirhosseini et al., 2017; Martínez et al., 2018; Popovic et al., 2018; Mashyakhy and Gambarini., 2019). Recently, Neelakantan et al (2010) and Przesmycka and Tomczyk (2016) have compared the efficacy of various methods for visualizing the canal and root morphology. These authors concluded that CBCT is accurate, high-resolution, and can be useful for detailed quantitative and qualitative descriptions of the RC anatomy, (Neelakantan et al., 2010; Filpo–Perez et al., 2015; Przesmycka and Tomczyk., 2016; Martinsa et al., 2020).

Some reviews have noted high global rates of a second canal in the anterior central and lateral incisors (20.4% and 25.3%), respectively (Martinsa et al., 2020), while some studies have reported greatly varying numbers of canals and canal types among the same teeth (Ahmad., 2015; Ahmed and Hashem., 2016; Bansal et al., 2018; Martins et al., 2019). All the published reviews that we identified have noted that knowledge of these preoperative variables could help clinicians anticipate more complex RC anatomic configurations, thus minimizing the possibility of lost canals during treatment. Investigators use various morphological characteristics to classify root canal systems e.g., the number of canals from orifice to apex, the sum of roots and number of canals in each root, or the number of isthmuses (Vertucci., 1984; Bansal et al., 2018), but the most widely used is Vertucci's classification, which classifies root canal systems into eight types.

Variations in the morphology of the canals and roots of maxillary and mandibular central or lateral incisor teeth have been noted in in vivo and in vitro studies (Vertucci., 1984; Saini et al., 1990; Caliskan et al., 1995; Al-Quadah and Awawdeh; 2006; Weng et al., 2009; Al-Fouzan et al., 2012; Aminsobhani et al., 2013; Altunsoy et al., 2014; Lin et al., 2014; Zhao et al., 2014; Arslan et al., 2015; Zhengyan et al., 2016; da Silva et al., 2016; Martins et al., 2017; Verma et al., 2017; Mirhosseini et al., 2017; Saati et al., 2018; Martins et al., 2018; Martínez et al., 2018; Popovic et al., 2018; Shemesh et al., 2018; Razumova et al., 2018; Mashyakhy M., 2019; Valenti-Obino et al., 2019; Mashyakhy and Gambarini., 2019; Pan et al., 2019; Bourzgui and Akarslan., 2020; Ghabbani et al., 2020; Baxter et al., 2020) (Table 1), and in case reports (Hwang and Min., 2005; Al-Madi., 2020) (Table 2).

However, only a few of those studies were original research by Saini et al., 1990; Al-Fouzan et al., 2012; Mashyakhy M., 2019; Mashyakhy and Gambarini., 2019; Ghabbani et al., 2020, or case reports by Al-Nazhan., 1991; Alenazy et al., 2019; Al-Madi., 2020, conducted in Saudi Arabia. Here we summarize the published Saudi studies and investigate the number of canals and root morphology of maxillary and mandibular anterior teeth and making comparisons with the global data in relation to the original researches or case reports.

Search Methodology: All peer-reviewed original research articles or case reports for maxillary and/or mandibular central and lateral incisors from 1980 to 2020 addressing root or root canal morphology of permanent teeth were included in this review. A systematic literature review was carried out using the PubMed, Science Direct, Scopus, Evidence-Based Dentistry, and Journal of Evidence-Based Dental Practice databases. The search terms used were: "root canal morphology", "root morphology", "case report for anterior maxillary and mandibular teeth", and "Saudi Arabian population". All irrelevant or duplicate articles were excluded; the full texts of whole original researches or case reports were screened and saved in a single folder. In addition, all volumes or issues of the Saudi Dental Journal and Saudi Endodontic Journal were manually investigated for related topics. Lastly, the article reference lists were checked for further eligible articles.

Data Collections Original Researches: A total of 29 original research studies (18 mandibular teeth, seven maxillary teeth, four both teeth) were identified. Nineteen of the maxillary teeth studies were clinical studies that used CBCT, and three were laboratory studies using the clearing technique. Seven of the mandibular teeth studies used CBCT and a single study used radiograph, while the other three used the clearing technique. Three of the studies were original Saudi research involving mandibular teeth (Al-Fouzan et al., 2012; Mashyakhy., 2019; Ghabbani et al., 2020), were done in Al Madinah Al Munawara, Jazan, and Riyadh, respectively.

Also, two Saudi studies, done in Riyadh and Jazan (Saini et al., 1990; Mashyakhy and Gambarini., 2019), involved maxillary teeth. The author names, the year the study was conducted, country, sample size, type of tooth, genders, and anatomical features and finding are given

in Table 1. Also, significant differences were recorded when comparing genders, sides, types of teeth, bilateral symmetry, and techniques used. The anatomical features and finding in relation to Vertucci's classification were investigated, including the number of roots, number of root canals and their configurations, and other radiographical or anatomical findings.

Table 1. Summary of clinical and laboratory morphological studies of roots and canals number, and canals' configuration of mandibular and maxillary anterior teeth conducted on SA and worldwide countries

Researcher (S), Year/Country	Anatomical Features & %, general finding Tooth Type/ Vertucci Classification Type (N %) Gender I II III IV V VI VII Others Two canal	Sig ↔ Teeth, Gender & Bilateral symmetry, Male: Female %
	Mandibular teeth	
Ghabbani et al, 2020/KSA, Al-Madinah Al-Munawara[3]	Central 24.6% 0.00% 21.5% 1.2% 2.4% 1.0% Lateral 25.6% 0.00% 20.6% 1.2% 7.1% 1.6% Males 45.2% 0.00% 46.9% 0.00% 6%, 1.7% Female 64.8% 0.00% 29.4%, 0.9%, 3.3% 1.4%	SD ↔ Type Teeth & SD ↔ Genders Low Symmetry SD↔Saudi& Non-Saudi *Male 300/ Females 106*
Mashyakhy M, 2019/ KSA, Jazan[4]	Central 73.7% 0.00% 26.3% 26.3% Lateral 69.2% 0.00% 29.8% 0.00% 1.0% 30.8% M/F 67.3%/79.4 0.0%/0.0% 32.7%/20.6% 2.7%/20/6%	SD ↔ Canal, Side, Type NSD- Gender Moderate Symmetry *M 48% Fe 52%*
Al-Fouzan et al, 2012/KSA, Riyadh[5]	Central 70% 0.00% 30% Lateral 70% 0.00% 30%	Very High symmetry
Baxter et al, 2020/ Germany[6]	Central 76.4% 22.3% 0.00% 0.7% 1.2% 22.6% Lateral 76.3% 21.4% 0.00% 0.00% 1.0% 24.3%	NSD ↔ Teeth, Age&SD ↔ Genders High Symmetry/ *M 116 / Fe 186*
Mirhosseini et al, 2019/ Iran[7]	Central 76.1% 0.00% 15.8% 0.6% 7.6% 23.9% Lateral 65.0% 0.6% 15.7% 0.9%) 17.9% 35.0%	SD ↔ Tooth Type Low Symmetry
Pan et al, 2019/ Malaysia[19]	Central 94.9% 0.00% 1.0% 0.00% 4.2% Lateral 87.8% 0.00% 3.8% 0.3% 8.3%	NSD↔ Gender& Side Low Symmetry */M 43.3 /Fem56.7*
Valenti-Obino et al, 2019/Italy[8]	Central 55.0% 34.3% 9.3% 0.6% 0.8% 45% Lateral 57.0% 35.7% 6.9% 0.0% 0.4% 43%	NSD↔ Teeth Type High Symmetry
Razumova et al, 2018/ Russia[20]	Central 99.4% 0.00% 0.6% Lateral 99.2% 0.8% 0.0%	High Symmetry
Saati et al, 2018/Iran[9]	Central 54.5% 0.00% 34.2% 0.00% 11.3% Lateral 56.5% 0.00% 26.1% 0.00% 17.4%	NSD ↔Teeth Type NSD ↔ Gender/ High symmetry
Martins et al, 2018, China & Portugal[10]	Central 72.6% 2.40% 0.8% 0.00% 0.3% VII; 0.5% Lateral 70.1% 6.10% 23.1% 0.00% 0.2% VII; 0.3%	SD ↔Ethnics Moderate Symmetry
Martínez et al, 2018/ Belgium & Chile[11]	Central 60.50% 0.58% 32.18% 0.00% 4.02% VII; 0.58%, X; 1.15% Central 59.65% 0.58% 37.44% 0.00% 1.75% VII; 000% X; 0.58%	SD ↔ Ethnics Moderate Symmetry

Table 1. continue

Popovic et al, 2018/ Serbia[12]	Central 68.7% 7.2% 22.0% 0.00% 1.2% Lateral 72.0% 4.7% 22.0% 0.00% 1.2%	NSD↔ Tooth Type & SD ↔ Gender Moderate symmetry
Shemesh et al, 2018/ Israel[13]	Central 51.2%, 5.77% 39.15% 1.24% 0.62% 1.87% Lateral 56.96% 5.51% 35.83% 0.46% 0.00% 1.53%	NSD↔ Tooth Type & SD↔ Genders Moderate symmetry/ *M 653/ F 855*
Verma et al, 2017/ India[14]	Central 68.3% 11.0% 15.3% 1.8% 3.8% M 15.2% Lateral 65.0% 13.3% 5.3% 3.0% 3.5% F 20.4% 1root &1canal 66.5% Man; 2canals 33.5%RC&L, 36.5%L	SD ↔ Side & SD ↔ Gender Moderate Symmetry& *103 M/97F*
Zhengyan et al., 2016/ China[15]	Central 96.3% 0.2% 2.7% 0.1% 0.75% 3.8% Lateral 89.4% 1.1% 7.7% 0.3% 0.70% IX; 0.3% 10.8%	SD ↔ Tooth Type& Side, Gender& Age Low Symmetry- *M 923 / Fee 802*
Arslan et al, 2015/ Turkey[16]	Central 51.9% 4.3% 41.6% 0.00% 0.5% 1.6% Lateral 37.2% 5.2% 55.2% 0.00% 1.7% 0.6%	SD ↔ Gender & Low Symmetry 54 Females &47 Males
Altunsoy et al, 2014/ Turkey[21]	Central 80.7% 0.6% 1.3% 4.2% 13.1% Lateral 76.7% 1.6% 1.4% 5.9% 14.4%	SD ↔ Gender & Moderate Symmetry- *410 Male /417 Female*
Lin et al, 2014/ China[30]	Central 89.1 % 2.4 % 6.2% 1.7 % 0.6 % Lateral 74.5 % 3.7 % 19.3% 2.1 % 0.4 Type III incisors most prevalent, followed types II, IV & V	SD↔ Tooth Type SD ↔ Gender High Symmetry *M 163 / Fe 190*
Zhao et al., 2014/ China[31]	All C& L single root/Central6.7%/Lateral7.4%/ III prevalent 2root canals 9.8% in 31-40 years in Cs& 21.5% (31-40 years) in L	SD↔ Tooth type & Age Groups Moderate Symmetry

Table 1. Continue

Aminsobhani et al, 2013/ Iran[32]	Central 72.7% 11.3% 4.7% 7.7% 3.6% 27.3% Lateral 70.6% 7.10% 3.7% 15.4% 3.2% 29.4%	NSD ↔ Gender High Symmetry/ *M 620/Fe 626*
AlOah&Awdeh, 2006 / Jordan[33]	73.8% 26.2% 8.7% had two separate apical foramina.	
Vertucci FJ, 1984/ USA[22]	Central 70% 5% 22% 0.00% 3% Lateral 75% 5% 18% 0.00% 2%	Moderate Symmetry
	Maxillary teeth	
Mashyakhy & Gambarini, 2019 / KSA, Jazan[17]	Central 100% Lateral 100%	NSD ↔ Gender Very-High Symmetry *M52/Fe 48*
Saini et al, 1990/ SA,Riyadh[18] (Shovel-shaped incisors)	C-Type I;0.90%, II; 3.73%, III; 3.25%, IV; 7.8%/ Type II C 4.48% L-Type I; 1.96%, II; 6.81%, III; 1.21%, IV:10% Type II L 11.11%	NS ↔ Genders Dens - invaginatus
Martins et al, 2018/ China & Portugal[10]	Central Asian 100% and White 100% Lateral Asian 100% and White 100%	SD ↔Ethnics
Pan et al, 2019/ Malaysia[19]	Central 94.9% 5.1% Lateral 87.85 12.3%	NSD ↔ Gender NSD ↔ Side High Symmetry
Razumova etal,2018/Russia[20]	Central 100% Lateral 100%	High Symmetry
Martins et al, 2017/ Portugal[35]	Central 100% Lateral 100%	Very High Symmetry
de Silva et al, 2016/ Brazil[36]	Central 98% 1.0% 0.00% 0.00% 1.0% Lateral 96% 3.5% 0.00% 0.00% 0.5%	Moderate Symmetry
Altunsoy et al, 2014/ Turkey[21]	Central 99.5% 0.00% 0.4% 0.00% 0.1% Male ↑ Lateral 99.7% 0.00% 0.00% 0.00% 0.3% Central 96.7% 1.3% 0.7% 0.00% 1.3% Female ↓ Lateral 98.3% 0.7% 0.00% 0.5% 0.5%	SD ↔ Gender Moderate Symmetry *Male 410 /Females 417*
Weng et al, 2009/ China[37]	Central 95.8% 4.2% 0.00% 0.00% 0.00% Lateral 91.4% 2.9% 1.40% 0.00% 4.3%	Moderate Symmetry
Caliskan et al, 1995/ Turkey[38]	Central 100% Lateral 78.05% 2.44% 14.63% 0.00% 4.88%	Moderate Symmetry
Vertucci FJ, 1984/ USA[22]	Central 100% Lateral 00%/24 lateral canal MAXC;1% cervical,6% medial,93% apical	Very High Symmetry

Few studies in the peer-reviewed literature have investigated the canal and root configuration of the maxillary arches (Table 1). A single Saudi study was carried-out by Mashyakhy and Gambarini., 2019 among a subpopulation in Jazan city, and they found that all maxillary central and lateral incisors were Vertucci's classification Type I. Another earlier study, published earlier, investigated shovel-shaped and dens invaginates in maxillary central incisors (Saini et al., 1990). Other international studies (Russian, Chinese, and Portuguese participants) reported the same percentages (100%) for their maxillary central and lateral incisors samples, and most of them were Vertucci's classification Type I (Martins et al., 2017; Razumova et al., 2018; Bourzgui and Akarslan., 2020). Other studies conducted in American, China, and Turkey (Vertucci., 1984; Caliskan et al., 1995; Weng et al., 2009 Altunsoy et al., 2014) reported Type I and Type III rates of 78.05% to 99.5%, respectively, for maxillary incisors. Vertucci's classification Type V was recorded in 1–4.88% of patients from China, Turkey, and Brazil (Weng et al., 2009; Altunsoy et al., 2014; da Silva et al., 2016).

Case Reports: Twenty-nine clinical case reports are listed in Table 2: 25 cases involving maxillary teeth and four cases including mandibular teeth. Among these, three cases were related to Saudi patients (Al-Nazhan S., 1991; Alenazy et al., 2019; Al-Madi EM., 2020). Most of the maxillary case reports were central incisors teeth ''21 of 25 in the maxilla''; nine cases were males and 14 females; and 14 cases were on the left side. Most canals were Vertucci's classification Type IV in both arches, and most of the teeth had two roots. Relatively few cases relating to the mandibular arch have been published. The following information's were gathered: the author(s) name, time of publication of the case report, place of documentations, gender, type and side of involved tooth/ teeth, number of canals, roots or canal configuration according to Vertucci's classification, and special finding associated with the treated case, if any. Figure 1 shows a radiograph of a treated case for male on the left lateral incisor maxillary tooth and other mandibular case for a female patient on the left central incisor tooth.

RESULTS AND DISCUSSION

Knowledge of tooth morphology is main basis for science of RCT. Today, root apex is not the only area in RCT science but the idea of three-dimensional RC filling implies that although working length and maintaining it is more important, access to all complications of canal inside is also crucial in order to RC filling (Castelucci., 2015; Bansal et al., 2018). Worldwide, the maxillary and mandibular central and lateral incisors are among the most likely teeth to require RCT (Castelucci., 2015; Filpo–Perez et al., 2015; Ahmed and Hashem., 2016; Martinsa et al., 2020; Baruwa et al., 2020).

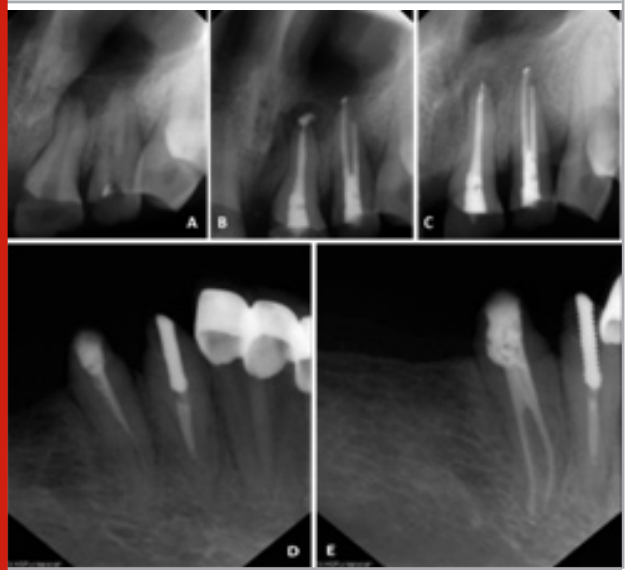
Table 2. Summary of previous case reports of Maxillary and Mandibular central and lateral incisors with variations as gender, tooth type, side, and canal morphology according to Vertucci's Classification

Author (s) & Year Publication	Country/ Gender	Vertucci's Classification and Tooth Type	Canal (s)	Root (s)	Special findings
		Maxillary Teeth			
Present Case	Figure 1 (A-C)/M	V/ Lateral, left	1	2	Non - Vital
Al-Madi et al, 2020[39]	Saudi Arabia/F	IV/ Central, left	2	2	Re-treatment
Al-Nazhan S, 1991[40]	Saudi Arabia/F	IV /Central, left	2	2	Enamel Hypoplasia
Buonvere & Buoivere, 2019[42]	Italy/F	VIII/ Central, left	1	3	Non-vital
Elbay et al, 2016[43]	Turkey/F	IV/ Central, right	2	2	Non-vital
		IV/ Lateral, right	2	2	
Sharma et al, 2014[44]	India/M	V/ Central, right	1	2	Crown dilaceration
Krishnamurti et al,2012[45]	India /F	Central, right	2	1	Root resorption
Kottoor & Murugesan, 2012[46]	India/M	Lateral, left	1	4	Non-vital
Nabavizadeh et al,2010[47]	Iran /M	IV/ Central, left	2	2	Non-vital
Gondim et al, 2009[48]	Brazil/M	Central, right	2	3	---------
Shokouhinejad et al, 2009[49]	Iran /F	Lateral, left	1	2	Non-vital
Rodrigues & Silva, 2009[50]	Brazil/F	IV/ Central, right	2	2	Non-vital
Sheikh-Nezami MM, 2007[51]	Iran /M	Central, right	1	3	Non-vital
Sponchiado et al, 2006[52]	Brazil /F	IV/ Central, left	2	2	---------
Lin et al, 2006[53]	China /F	IV/ Central, right	2	2	----------
Benenati FW, 2006[54]	--------	IV/ Central, left	2	2	Non-vital
Khojastehur & Khaya, 2005[55]	Iran/F	IV/ Central, left	2	2	Non-vital
Zaitoun &tMackie, 2004[56]]	U K /F	VIII/ Central, right	1	3	Non-vital
Genovese & Marsico,2003[57]	Italy /F	IV/ Central, right	2	2	Non-vital
Cimilli & Kartal, 2002[58]	Turkey/M	IV/ Central, left	2	2	Fusion of roots
Cabo-Vale & Gonz-Goez, 2001[59]	Spain/F	IV/ Central, right	2	2	Non-vital
Mangani & Ruddle, 1994[60]	Italy /F	Central, right	1	4	Dens invaginatus
Lambruschini & Camps, 1993[61]	France /F	IV/ Central, right	2	2	--------
Hososmi et al, 1989[62]	Japan/M	Central, right	2	3	Gemination
Mader & Konzelman, 1980[63]	U S A/M	IV/ Central, left	2	2	-----
Sinai & Lustbader, 1980[64]	U S A/--	IV/ Central, right	2	2	Incomplete apical formation
		Mandibular Teet			
Present Case	Figure 1 (D-E) /F	V/ Central, left	2	1	Re-treatment
Al Enazay et al., 2019[41]	Saudi Arabia /F	V/ Central, left	1	2	Re-treatment
		III/ Lateral, left	1	1	
		III/ Central, right	1	1	
		IV/ Lateral, right	2	1	
Hwang & Min, 2005[65]	South Korea	IV/ Central, R & L	2	2	Re-treatments
		IV/ Lateral, left	2	2	
Kabak & Abbott, 2007[66]	Belarusia/M	II/ Central, right	2	2	Non -vital
		II/ Lateral, R & L	21	22	
Guan et al., 2009[67]	China	IV Central, R & L	2	2	
		IV/ Lateral, R & L	2	2	----------

Usually, there is just one canal in the anteriors incisors (Vertucci., 1984; Altunsoy et al., 2014; Razumova et al., 2018; Mashyakhy and Gambarini., 2019; Pan et al., 2019). However, a second canal or other variations do occur (Al-Quadah and Awawdeh., 2006; Aminsobhani et al., 2013; Arslan et al., 2015; Zhengyan et al., 2016; Verma et al., 2017; Saati et al., 2018; Martins et al., 2018; Martínez et al., 2018; Popovic et al., 2018; Shemesh et al., 2018; Ghabbani et al., 2020). Anteriors incisors are the smallest human permanent teeth; incisors have complex roots and canals, especially mandibular incisors. Incisors can be single-rooted, have double roots or canals, a lateral

branch of a root canal, apical ramification, or apical furcation; this variability can complicate RCT (Hwang and Min., 2005; Kabak and Abbott., 2007; Guan et al., 2009; Elbay et al., 2016; Alenazy et al., 2019; Buonvivere & Buonvivere., 2019).

Figure 1: Maxillary left lateral incisor with preapical pathosis (A), teeth after RCT for lateral with two canals (B), follow-up after 18 months (c). Mandibular left lateral incisor with incomplete RCT (D), tooth after RCT with two root canals (E).



Here we review local and international studies and describe the numbers of canals and root morphology of maxillary and mandibular anterior teeth.Starting in the 20th century, the outside and inner structure of the maxillary and mandibular anterior teeth have been evaluated using in vivo and in vitro techniques. The in vivo techniques include clinical evaluation during RCT, retrospective assessment of patients' files, and radiographic analysis using conventional and advanced radiographic methods, such as CBCT. The in vitro techniques include root sectioning, canal staining, tooth clearing, microscopic and radiographic examinations using traditional or conventional x-rays, and 3-D techniques, such as micro-computed tomography (Neelakantan et al., 2010; Grover and Shetty., 2012; Filpo–Perez et al., 2015; Ahmad., 2015; Ahmed and Hashem., 2016; Przesmycka and Tomczyk., 2016; Martins et al., 2019; Martinsa et al., 2020).

For mandibular central incisors, multiple studies have been published, conducted in various countries. The percentages of Vertucci's classification Type I for central incisors were above 70% and exceeded 90% in some local Al-Fouzan et al., 2012; Mashyakhy., 2019;, and international (Al-Quadah and Awawdeh., 2006; Altunsoy et al., 2014; Mirhosseini et al., 2017; Baxter et al., 2020) studies. Ghabbani et al 2020, ''Saudi Arabia'' reported a lower percentage. Similar percentages were documented in other countries, such as Italy, Iran, Israel, and Turkey (Arslan et al., 2015; Saati et al., 2018; Shemesh et al., 2018; Valenti-Obino et al., 2019).

Also, the rate of Type I Vertucci's classification among the mandibular lateral incisors of Saudis has been reported to be as high as 70% (Al-Fouzan et al., 2012; Mashyakhy., 2019),and similar rates have been reported in the US, Turkey, Iran, Portugal, and Germany, (Vertucci., 1984; Altunsoy et al., 2014; Mirhosseini et al., 2017; Martins et al., 2018; Baxter et al., 2020). The frequency of Vertucci's Type III in mandibular lateral incisors was recorded as 20–30% in Saudi studies by Al-Fouzan et al., 2012; Mashyakhy., 2019; Ghabbani et al., 2020; and similar findings were reported by (Satti et al., 2018) in Iran, (Martins et al., 2018) among patients from China and Portugal, and Turkish patients by (Arslan et al., 2015), and less than 20% amongst patients from Iran, Belgium & Chile, and Germany (Mirhosseini et al., 2017; Martínez et al., 2018; Baxter et al., 2020).

Local studies in Saudi Arabia have reported that around 30% of mandibular teeth had two canals (Al-Fouzan et al., 2012; Mashyakhy., 2019; Ghabbani et al., 2020). This is well supported by Ahmed et al., 2015. who reported that the two-canal configuration is the most common accessory anatomical variation in single-rooted mandibular anteriors (Ahmed and Hashem., 2016). This is in line with other studies conducted in, Iran, India, Serbia, and Germany (Mirhosseini et al., 2017; Verma et al., 2017; Popovic et al., 2018; Baxter et al., 2020) but a higher percentage was detected in Turkey, Israel, and Italy (Arslan et al., 2015; Shemesh et al., 2018; Valenti-Obino et al., 2019). Also, two canals were more common amongst females than males (Verma et al., 2017), but this trend was reversed in a Turkish population (Altunsoy et al., 2014). Finally, mandibular lateral incisors with two canals were more than central incisors among a Chinese population (Zhao et al., 2014). Vertucci's classification Type IV was the least common in all studies, and Type V was present in small percentages within the screened patients in most of the studies (Table 1).

The root canal morphology can change over time. Changes due to normal physiological aging usually occur because of secondary dentine deposition (Johnstone and Parashos., 2015). A recent study has reported high variability in root canal morphology of mandibular anterior incisors. Vertucci's classification Type VII was detected in a local study conducted in Al Madinah Al Munawara (Ghabbani et al., 2020). Also, a similar canal Type was reported in those studies that included participants from Turkey, China, Portugal, Belgium, Chile, and Israel (Arslan et al., 2015, Martins et al., 2018; Martínez et al., 2018; Shemesh et al., 2018;). Other variations were shown in the form of Types IX and X in China and Belgium (0.58–1.15%, respectively), and in China alone (10.8%) (Weng et al., 2009; Bourzgui and Akarslan., 2020).

Compared to the mandibular arch, relatively few studies have addressed maxillary anteriors (Vertucci., 1984;

Caliskan et al., 1995; Weng et al., 2009; Altunsoy et al., 2014; da Silva et al., 2016; Martins et al., 2017; Razumova et al., 2018; Mashyakhy and Gambarini., 2019; Pan et al., 2019; Bourzgui and Akarslan., 2020). Both central and lateral maxillary teeth typically start with a single canal and end in a single root. Rates of up to 100% Vertucci's Classification Type I have been reported, including in a single local Saudi study (Mashyakhy and Gambarini., 2019), and studies carried out in Russia, America, China, Portugal, and Turkey (Vertucci., 1984; Caliskan et al., 1995; Martins et al., 2017; Razumova et al., 2018; Bourzgui and Akarslan., 2020), but lower rates have been reported amongst central maxillary teeth in studies conducted in China, Brazil, and Malaysia (Weng et al., 2009; da Silva et al., 2016; Pan et al., 2019).

On the other hand, a rate of 78–91%; Weng et al., 2009 was recorded for maxillary lateral incisors in Turkey, China, and Malaysia (Caliskan et al., 1995; Pan et al., 2019;). Few studies reported a moderate percentage of two canals in maxillary anteriors or incisors, with lower rates than in mandibular teeth. Vertucci's classification Type III and IV were relatively rare. In a study conducted by Altunosy et al., 2014 among a Turkish population, the authors reported that two canals were more common in males than females; another study reported significant differences in canal number and configuration when comparing populations from China and Portugal (Bourzgui and Akarslan., 2020).

In this review, we conducted a gender comparison in relation to the number of canals, the number of root canals, and root canal configurations (according to Vertucci's classification). Both studies among Jazanian publications showed no significant differences between gender (Mashyakhy., 2019; Mashyakhy and Gambarini., 2019), while a study conducted in Al Madinah Al Munawara by Ghabbani et al., 2020 showed a significant difference between genders. This could be explained by the uniform sample of the population in Jazan, and mixed populations in the study conducted by Ghabbani et al., 2020 and both studies conducted in Turkey by Altunsoy et al., 2014 and Arslan et al., 2015, while no significant differences were recorded in Malaysia in both arches Pan et al., 2019, or both Iranian studies by Aminsobhani et al., 2013; Saati et al., 2018).

The bilateral symmetry between sides in relation to the type of teeth and canals configurations as well as root numbers, Al-Fouzan et al., 2012 reported a high or typical symmetry between the extracted mandibular teeth in relation to the number of canals and canal configurations. This is consistent with studies conducted in Europe 'Italy and Germany'' (Valenti-Obino et al., 2019; Baxter et al., 2020), Asia ''China and Iran'' (Lin et al., 2014; Saati et al., 2018), and the US (Vertucci., 1984), which have also reported high symmetry, which might be related to the racial type and uniform sample types. Mashyakhy M., 2019, Mashyakhy and Gambrini., 2019 reported moderate bilateral asymmetries in central and lateral maxillary and mandibular incisors in relation to some canals and canals configurations. This finding is similar to those from other countries, such as studies conducted in India, China, Portugal, Belgium, Serbia, and Israel (Verma et al., 2017; Martins et al., 2018; Martínez et al., 2018; Popovic et al., 2018; Shemesh et al., 2018).

In Al Madinah Al Munawara, Ghabbani et al., 2020 reported low symmetry among the participants. This is likely because Muslims from all around the world visit this city and many of them stayed for a long time. Also, his sample was a mix of Saudis and non-Saudis, and a significant difference was recorded between these groups. International studies conducted in Iran, China, Turkey, and Malaysia, including mixed races of (Malawians, Chinese, and Indianans) addressing maxillary incisors have reported a low percentage of bilateral symmetry (Arslan et al., 2015; Zhengyan et al., 2016; Mirhosseini et al., 2017; Pan et al., 2019).

A high bilateral symmetry for maxillary teeth was recorded by Mashyakhy and Gambarini., 2019 among Saudis subpopulations, which was consistent with international findings among subjects from America, Portugal, Russia, and Malaysia by Vertucc., 1984; Martins et al., 2017, Razumova et al., 2018; Pan et al., 2019, while moderate bilateral symmetry was detected among samples involving the mandibular incisors among Chinese, Turkish, and Brazilin participants (Weng et al., 2009; Altunsoy et al., 2014; da Silva et al., 2016). Overall, the Saudi studies documented significant differences between central and lateral teeth regarding Vertucci's classification of the canal and root canal type, or number and configurations. Similar findings reporting significant differences between mandibular teeth type were found in Germany and India (Verma et al., 2017; Baxter et al., 2020), while the opposite was documented in Turkey, Serbia, Malaysia, and Israel, (Altunsoy et al., 2014; Popovic et al., 2018; Pan et al., 2019; Valenti-Obino et al., 2019;), and with mixed results in Iran and China (Aminsobhani et al., 2013; Lin et al., 2014;).

Most case reports of maxillary and mandibular anterior teeth described a different pulp morphology or number of canals, as well as roots (Sharma et al., 2016 - Baruwa et al., 2020). Some Saudis case reports have mentioned dissimilarities in canal anatomy in relation to gender, arch, and tooth type ''Table 2 and Figure 1'' There are 25 case reports for maxillary teeth (Table 2) (Al-Nazhan., 1991; Alenazy et al., 2019; Al-Madi., 2020) and (Sinal & Lustbader., 1984; Buonvivere and Buonvivere., 2019). Two local cases were reported, by Al-Nazhan., 1991and Al-Madi et al., 2020. The first case was for a female patient with maxillary left central incisor, while. the second reported a female patient with re-treatment for a left maxillary central incisor tooth. The canal morphology for both cases was Vertucci's classification Type IV, with two canals and two roots. The second case was associated with enamel hypoplasia, while the first was discovered during re-treatment of the teeth.

Figure 1 (A–C) shows a male patient with a non-vital left central maxillary incisor with Vertucci's classification Type V. In the maxillary teeth, there were more cases

among females than males (15 vs. 10 cases), most were central incisors (22), and left-sided (15 vs. 10 right-sided), and all of the published reports involved a single tooth only. Both published cases by Al-Nazhan., 1991; Al-Madi et al., 2020 and were consistent with the international case reports (Mader and Konzelman., 1980; Sinal and Lustbader., 1984; Lambruschini and Camps., 1993; Mangani and Ruddle., 1994; Cabo-Valle and Gonzalez-Gonzalez., 2001; Cimilli and Kartal., 2002; Genovese and Marsico., 2003; Khojastehpour and Khayat., 2005; Sponchiado et al., 2006; Lin et al., 2006; Benenati., 2006; Krishnamurti et al., 2012; Elbay et al., 2016) in relative to the tooth type, side, gender, and Vertucci's classification (17 cases out of 25 with Type IV), as well as canal configuration and root numbers.

Central maxillary incisures have a tendency for a more abnormal canal and root configurations due to the presence of dens invaginatus and shovel-shaped incisors (Saini et al., 1990; Mangani and Ruddle., 1994; Ahmed and Hashem., 2016), enamel hypoplasia (Al-Nazhan., 1991), and fusion roots (Cimilli and Kartal., 2002). Saini et al., 1990, measured the rate of shovel-shaped incisors among Saudis and detected different types among central incisors and different classification of dens invaginatus among the participants. Baruwa et al., 2020 reported a failure rate greater than 7% among maxillary central incisors due to either missed canals associated with a periapical lesion in 116 canals or with 119 canals without periapical lesions among 1693 screened teeth.

We identified relatively few case reports involving mandibular teeth. However, there were many research studies addressing central and lateral incisor mandibular teeth (Table 2). Al Enazay et al., 2019 reported the case of a Saudi female patient with unusual canal configuration and anatomy of the roots in her mandibular central and lateral incisors during re-treatments of the same teeth. This case showed the four mandibular teeth having different Vertucci's classification: Type V for the center-left, Type IV for lateral right, while lateral left and central right were with Vertucci's classification Type III (Alenazy et al., 2019). Internationally, Guan et al. (China) and Hwang and Min (South Korea) (Hwang and Min., 2005; Guan et al., 2009) reported cases with Vertucci's classification Type IV for all mandibular central and lateral incisors. In these studies, Type IV is relatively more common that in our cases, while (Kabak and Abbotto., 2007) from Belarusians had reported Vertucci's classification Type V for the same teeth.

Figure 1 (D and E) shows the mandibular left central incisor of a female patient in with Vertucci's classification Type V. These differences in the types might be explained in multiple ways, such as differences in ethnicities, age, and the genetic factors of the patients. Ahmed et al. noted that the prevalence of accessory root/root canal dissimilarities in the mandibular anterior teeth is greater than maxillary complements (Grover et al., 2012; Johnstone and Parashos,. 2015; Ahmed and Hashem., 2016). Root canal configuration types 2-2 and 1-2 are the most common accessory anatomical variations in single-rooted mandibular anteriors (Ahmed and Hashem., 2016). Due to the wide morphological variance of the root and root canal system in human anterior teeth, dental general practitioners and specialists should be aware of such anatomical variations, thereby decreasing the risk of failure because of inadequate debridement of inaccessible or undetected parts of the RCS. Recently developed diagnostic devices, the latest endodontic (and periodontal) techniques, and improvements in RCT biomaterials and machines are likely to improve RCT outcomes for patients (Ahmed and Hashem., 2016).

CONCLUSION

From this review the concluding remarks can be drown; The Saudi data and data gathered internationally in relation to canal number, root canal configuration was largely consistent. Type I Vertucci's classification of canal configuration is the most common type in both arches, followed by Type III. Variations are frequent in the mandibular teeth. Other types of Vertucci's classification were present in all populations, but at lower rates. The bilateral symmetry of canal and root numbers and configuration vary across populations and genders. All reported cases describing maxillary teeth included only a single tooth, while most of the cases involving mandibular anterior teeth described an unusual canal configuration or root canal number. Dentists should be familiar with the variations in canal numbers and configuration. Also, dentists should know how to use at least read the output of new technologies for visualizing root canal systems.

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