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CBCT based study to analyze and classify root canal morphology of maxillary molars – A retrospective study

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Abstract. – OBJECTIVE: The study aims to evaluate maxillary molars' root and root canal morphology among the Saudi population using Cone-Beam Computed Tomography scanning (CBCT).

SUBJECTS AND METHODS: Retrospectively, the CBCT scans of 483 Saudi nationals were evaluated to identify the number of roots and root canals in maxillary first and second molars. The records were tabulated and classified according to Vertucci and a new system for root and canal classification given by Ahmed and Dummer. Fisher's exact test was used to analyze the data statistically. To check for symmetry, comparisons were made between all the maxillary first molars (MFM's) and maxillary second molars (MSM's) on opposing quadrants. Inter Observer variability was seen using Cohen's Kappa test.

RESULTS: MFM's presented with three roots with Type II Vertucci canal configuration (VC) commonly seen among them. MSM's had more variations in the number of roots and canals, although three roots and Type I VC were predominantly seen. When comparing the two genders statistically significant difference was observed in both maxillary molars at a 5% level using Fisher's exact test. Three roots with four canals (3R4C) were predominantly observed in the MFM's (85.6%) and three roots with three canals (3R3C) identified in 51.95% were more common than 3R4C (43.55%) in MSM's. Both the maxillary molars bilaterally, exhibited a high percentage of symmetry in root and canal configurations.

CONCLUSIONS: Identification of root canal morphology of molars would reduce the chances of root canal failures by making sure all canals are obturated. This study provides supplemental information about the root canals of maxillary molars in a Saudi Arabian subpopulation.

Key Words:
CBCT, Endodontics, Maxillary molars, Root canal morphology.

Introduction

Non-surgical endodontic treatment has an 85-95% success rate, mainly when all procedures from diagnosis to three-dimensional sealing of the root canal space are carefully performed[1]. In order to accomplish such high rates of success and render the natural tooth disease-free, a detailed understanding of the root canal morphology is essential[2]. Moreover, the success rate is known to decrease significantly, due to the inability to detect and debride the root canals completely[3]. The root canal system is complex and intricate in most teeth and more so in the maxillary molars due to extra canals[3-5]. The mesio-buccal root (MBR) has two canals and anastomosis between them in maxillary molars, although these incidences vary among individuals of different ethnicities[6-12].

Historically, various methods were used to study the root canal morphology, but with the ad-

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vent of CBCT imaging, a 3D view of the root canal space is observable and has been proven to be very effective for this purpose[2,13,14]. CBCT scans can enhance the understanding of root canal anatomy, potentially improving the outcome of endodontic treatment[10]. Although several studies have utilized CBCT to analyze the morphology and symmetry of maxillary molars[3,10-12,15,16], the present study holds importance because only a handful of such studies in Saudi Arabia compared the first and the second molars using Vertucci classification[9]. No other study has utilized the newer classification given by Ahmed et al[17] to classify and compare the maxillary molars in Saudi population.

The present study aimed to determine and classify the root and root canal morphology of maxillary molars in the Saudi population, evaluate for bilateral symmetry, and determine any gender-based correlation.

Subjects and Methods

Study Population and Ethical Approval

Data were collected from College of Dentistry, Prince Sattam Bin Abdulaziz University (PSAU) using Carestream CS9300 (Carestream Dent LLC, Atlanta, GA, USA) CBCT machine with a voxel size of 180-300 mm and field of view (FOV) of 10x10 cm. The remaining data was collected from College of Dentistry, Dar Al Uloom University in Riyadh using Kavo OP3D Pro (KaVo Imaging, Hatfield, PA, USA) CBCT machine using similar voxel sizes and a FOV of 8x8 cm. Ethical approval was obtained from the Institutional Review Board, College of Dentistry, Prince Sattam Bin Abdulaziz University Alkharj, Saudi Arabia, with an ethical clearance number IRB PSAU2020029. A total of 483 scans were retrospectively analyzed out of which 264 were males and 219 were females. The scans evaluated were of maxillary first and second molars in Saudi nationals aged between 18-65 years. Only non-distorted CBCT scans of fully formed roots were accepted, which was around 69.83% of the total scans performed. Scans of previously endodontically treated teeth, or teeth with full coverage restorations or metallic restorations were excluded to limit the artifacts. The data for accepted scans of molars based on the aforementioned criteria is illustrated in (Figure 1).

The scans were documented based on the number of roots and root canals and classified according to Vertucci classification (VC) and a new classification system for classifying root and root canal morphology. Further, scans that included first molars and second molars on either side respectively were compared for symmetry in all three planes independently by two experienced endodontists, and a consensus was reached.

Statistical Analysis

The SPSS version 26 (IBM Corp., Armonk, NY, USA) software was used for data entry. Fisher exact test was used to evaluate differences in root and canal morphologies. The level of significance was set at 0.05 ($p \leq 0.05$), and in cases of high significance, it was kept at 0.01 ($p \leq 0.01$).

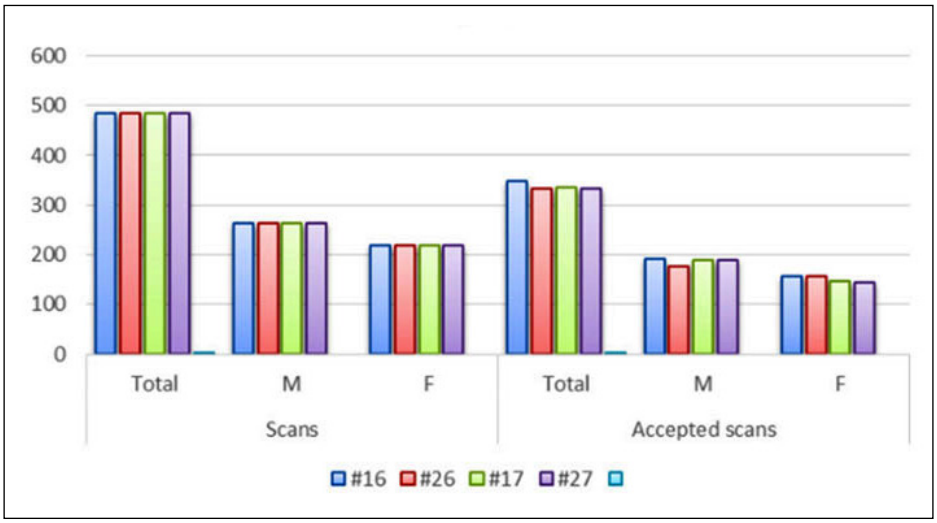

Figure 1. Demographics.

Table I. Distribution of maxillary molar teeth roots according to Gender.

Tooth	1 root		2 root		3 root		4 root		5 root	
16	0		0		349 (100%)		0		0	
	M	F	M	F	M	F	M	F	M	F
	0	0	0	0	191 (54.73%)	158 (45.27%)	0	0	0	0
26	0		0		332 (100%)		0		0	
	0	0	0	0	176 (53.01%)	156 (46.99%)	0	0	0	0
17	3 (0.90%)		12 (3.60%)		317 (94.60%)		3 (0.90%)		0	
	1 (0.30%)	2 (0.60%)	6 (1.80%)	6 (1.80%)	179 (53.40%)	138 (41.20%)	3 (0.90%)	0	0	0
27	2 (0.60%)		6 (1.80%)		321 (96.39%)		2 (0.60%)		1 (0.30%)	
	1 (0.30%)	1 (0.30%)	3 (0.90%)	3 (0.90%)	182 (54.60%)	139 (41.70%)	2 (0.60%)	0	1 (0.30%)	0

Note: M, Male; F, Female; 16, Right maxillary first molar; 26, Left maxillary first molar; 17, Right maxillary second molar; 27, Left maxillary second molar.

Cohen's Kappa test was used for inter-observer agreement while examining bilateral symmetry.

Results

Number of Roots

Three rooted maxillary first molars (MFM's) in 100% of the samples is shown in (Table I). The number of roots varied in the maxillary second molars (MSM's), ranging from one to four. The majority of the roots were three rooted, around 95.5% {94.6% on the right side (R) and 96.4% on the left (L)}, followed by two rooted MSM's which were around 2.7% (3.60% R and 1.8% L). Four rooted and single-rooted MSM's were seen in 0.75% (0.9% R and 0.6% L) of the scans, and five rooted MSM's were seen in 0.3% on the left side.

The Number of Roots and Root Canal Morphology

The teeth were categorized based on a number of roots and root canals and statistically analyzed for significance using Fisher's exact test with significance kept at 1% level as seen in Table II.

Table II. Distribution according to the number of roots and root canals in maxillary molars.

Type	1R1C	1R2C	2R2C	2R3C	3R3C	3R4C (mb2%)	4R4C	4R5C	5R5C
16	0 0.00%	0 0.00%	0 0.00%	0 0.00%	54 15.50%	295 84.50%	0 0.00%	0 0.00%	0 0.00%
26	0 0.00%	0 0.00%	0 0.00%	0 0.00%	44 13.30%	288 86.70%	0 0.00%	0 0.00%	0 0.00%
17	2 0.60%	1 0.30%	5 1.50%	7 2.10%	177 52.80%	140 41.80%	3 0.90%	0 0.00%	0 0.00%
27	2 0.60%	0 0.00%	4 1.20%	2 0.60%	170 51.10%	151 45.30%	2 0.60%	1 0.30%	1 0.30%

Note: 16, Right Maxillary First Molar; 26, Left Maxillary First Molar; 17, Right Maxillary second molar; 27, Left Maxillary second molar; 1R1C, one root with one canal; 1R2C, one root with two canals; 2R2C, Two roots with two canals; 2R3C, Two roots with three canals; 3R3C, Three roots with three canals; 3R4C, Three roots with four canals; 4R4C, Four roots with four canals; 4R5C, Four roots with five canals; 5R5C, Five roots with five canals; mb2, Second canal in the mesiobuccal root.

Table III. Distribution of canals according to Vertucci Classification in the mesiobuccal root of maxillary molars.

Vertucci configuration	16	26	17	27	p^a
I	58 (16.60%)	46 (13.90%)	187 (57.20%)	172 (53.10%)	0.000**
II	182 (52.10%)	170 (51.20%)	65 (19.90%)	69 (21.30%)	
III	3 (0.90%)	3 (0.90%)	0	0	
IV	106 (30.40%)	113 (34.0%)	75 (22.90%)	83 (25.60%)	

Note: 16, Right Maxillary First Molar; 26, Left Maxillary First Molar; 17, Right Maxillary second molar; 27, Left maxillary second molar; I, Originates and continues as one canal from the orifice to the apex; II, Originates as two canals from the orifice, merges into one canal before exiting the apex; III, Originates as one canal at the orifice, divides into two canals along its length and then merges into one canal before exiting the apex; IV, Originates and continues as two canal from the orifice to the apex.

First Molars

Three roots with three canals (3R3C) were seen in 14.3% (15.5% R and 13.3% L), and three roots with four canals (3R4C) were seen in 85.6% (84.5% R and 86.7% L).

Second Molars

One root with one canal (1R1C) was seen in 0.6% on both right and left sides. One root and two canals (1R2C) were seen in 0.3% only in the second molars on the right. Two roots and two canals (2R2C) were seen in 1.35% (1.5% R and 1.2% L). Two roots with three canals (2R3C) were also seen in 1.35% (2.1% R and 0.6% L). Three roots and three canals (3R3C) were seen in 51.95% (52.8% R and 51.1% L). Three roots and four canals (3R4C) were seen in 43.55% (41.8% R and 45.3% L). Four roots and four canals (4R4C) were seen in 0.75% (0.9% R and 0.6% L). Four roots and five canals (4R5C) and five root five canals (5R5C) were seen in 0.3% on the right-sided MSM's only.

Vertucci Classification

Table III shows the VC of the MBR of the maxillary molars. Maxillary first molars showed Type I, Type II, Type III and Type IV canal configuration and the maxillary second molars showed Type I, Type II and Type IV canal configuration (Figure 2). Significant statistical difference was seen when comparing different molars using Fisher's exact test with significance at 1% level.

Table IV shows the gender-based distribution of canal configurations based on VC in maxillary first and second molars. The statistically significant difference was seen on both the right and the left sides of the molars estimated using Fisher's exact test with significance at 5% level.

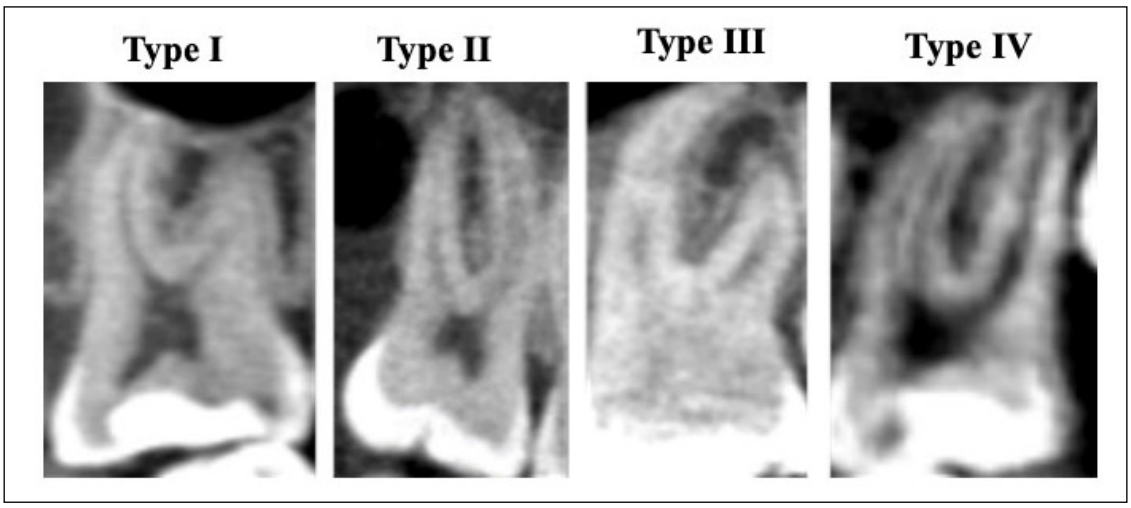

Figure 2. CBCT view of maxillary molars displaying different types of Vertucci canal configurations in the mesio-buccal root. Type I: originates and continues as one canal from the orifice to the apex; Type II: originates as two canals from the orifice, merges into one canal before exiting the apex; Type III: originates as two canals at the orifice, merges into one canal along its length and then again divides into two canals before exiting the apex; Type IV: originates and continues as two canals from the orifice to the apex.

Table IV. Gender wise distribution of canals according to Vertucci classification in the mesiobuccal root of maxillary molars.

Type	16			26			17			27		
	F	M	p^a	F	M	p^a	F	M	p^a	F	M	p^a
I	33 20.90%	25 13.10%	0.022*	25 16.00%	21 11.90%	0.042*	92 65.70%	95 50.80%	0.016*	86 61.90%	86 46.50%	0.014*
II	87 55.10%	95 49.70%	0.022*	88 56.40%	82 46.60%	0.042*	25 17.90%	40 21.40%	0.016*	25 18.00%	44 23.80%	0.014*
III	2 1.30%	1 0.50%	0.022*	2 1.30%	1 0.60%	0.042*	0	0	0.016*	0	0	0.014*
IV	36 22.80%	70 36.60%	0.022*	41 26.30%	72 40.90%	0.042*	23 16.40%	52 27.80%	0.016*	28 20.10%	55 29.70%	0.014*

Note: 16, Right Maxillary First Molar; 26, Left Maxillary First Molar; 17, Right Maxillary second molar; 27, Left maxillary second molar; I, Originates and continues as one canal from the orifice to the apex; II, Originates as two canals from the orifice, merges into one canal before exiting the apex; III, Originates as one canals at the orifice, divides into two canals along its length and then merges into one canal before exiting the apex; IV, Originates and continues as two canal from the orifice to the apex.
[a]Fishers exact test; *Significant at 5%.

Newer Classification

Table V shows classification for maxillary molars using the new classification system given by Ahmed et al[17]. This method eases the clinician to classify a tooth based on the number of roots and the presence and number of canals in each root. Figure 3 and Figure 4 portray the maxillary molars based on this new classification system.

Bilateral Symmetry

Table VI shows percentages of symmetry of roots and root canals in bilateral scans. 100% symmetry was seen in the number of roots in maxillary first molars on either side, and 96.4% of symmetry was seen in the number of roots in second molars. The percentage of agreement among evaluators was 98.4 giving a Cohen's kappa value of 0.96.

Regarding symmetry of root canals, 92.2% of the maxillary first molars had symmetrical canal morphologies and second molars had asymmetrical canal configuration of 83.7%. The percentage of agreement among evaluators was 80.95 giving a Cohen's kappa value of 0.61. A consensus was reached after independent evaluation and discussion with the radiologist.

Table V. Gender wise distribution of canals according to Vertucci classification in the mesiobuccal root of maxillary molars.

16		26		17		27	
Classification	n	Classification	n	Classification	n	Classification	n
$^{3}16MB^{1}DB^{1}P^{1}$	58	$^{3}26MB^{1}DB^{1}P^{1}$	46	$^{1}17^{1}$	2	$^{1}27^{1}$	2
$^{3}16MB^{2\text{-}1}DB^{1}P^{1}$	182	$^{3}26MB^{2\text{-}1}DB^{1}P^{1}$	170	$^{1}171^{\text{-}2}$	1	$^{2}27B^{1}P^{1}$	4
$^{3}16MB^{1\text{-}2\text{-}1}DB^{1}P^{1}$	3	$^{3}26MB^{1\text{-}2\text{-}1}DB^{1}P^{1}$	3	$^{2}17B^{1}P^{1}$	5	$^{2}27B^{2\text{-}1}P^{1}$	1
$^{3}16MB^{2}DB^{1}P^{1}$	106	$^{3}26MB^{2}DB^{1}P^{1}$	113	$^{2}17B^{1\text{-}2}P^{1}$	7	$^{2}27B^{1\text{-}2}P^{1}$	1
				$^{3}17MB^{1}DB^{1}P^{1}$	177	$^{3}27MB^{1}DB^{1}P^{1}$	170
				$^{3}17MB^{2\text{-}1}DB^{1}P^{1}$	65	$^{3}27MB^{2\text{-}1}DB^{1}P^{1}$	68
				$^{3}17MB^{2}DB^{1}P^{1}$	75	$^{3}27MB^{2}DB^{1}P^{1}$	83
				$^{4}17MB^{1}MB^{1}DB^{1}P^{1}$	1	$^{4}27MB^{1}MB^{1}DB^{1}P1$	2
				$^{4}17MB^{1}DB^{1}$ MP^{1} DP^{1}	2	$^{4}27MB^{1}DB^{1}DB^{1}P^{1}$	1
						$^{5}27MB^{1}MB^{1}DB^{1}MP^{1}DP^{1}$	1

Note: 16, Right Maxillary First Molar; 26, Left Maxillary First Molar; 17, Right maxillary second molar; 27, Left maxillary second molar; MB^{1}, one canal in the mesio-buccal root; $MB^{2\text{-}1}$, originates as two canals and terminates as one canal in the mesio-buccal root; $MB^{1\text{-}2\text{-}1}$, originates as one canal at the orifice, divides into two canals along its length and then merges into one before exiting the apex in the mesio-buccal root; MB^{2}, originates and continues as two canal from the orifice to the apex in the mesio-buccal root; B^{1}, one canals in the buccal root; $B^{1\text{-}2}$, originates as one canal then divides into two before exiting in the buccal root; $B^{2\text{-}1}$, originates as two canals merges and terminates as one canal in thebuccal root; DB^{1}, one canal in the disto-buccal root; P^{1}, one canal in the palatal root; MP^{1}, one canal in the mesio-palatal root; DP^{1}, one canal in the disto-palatal root.

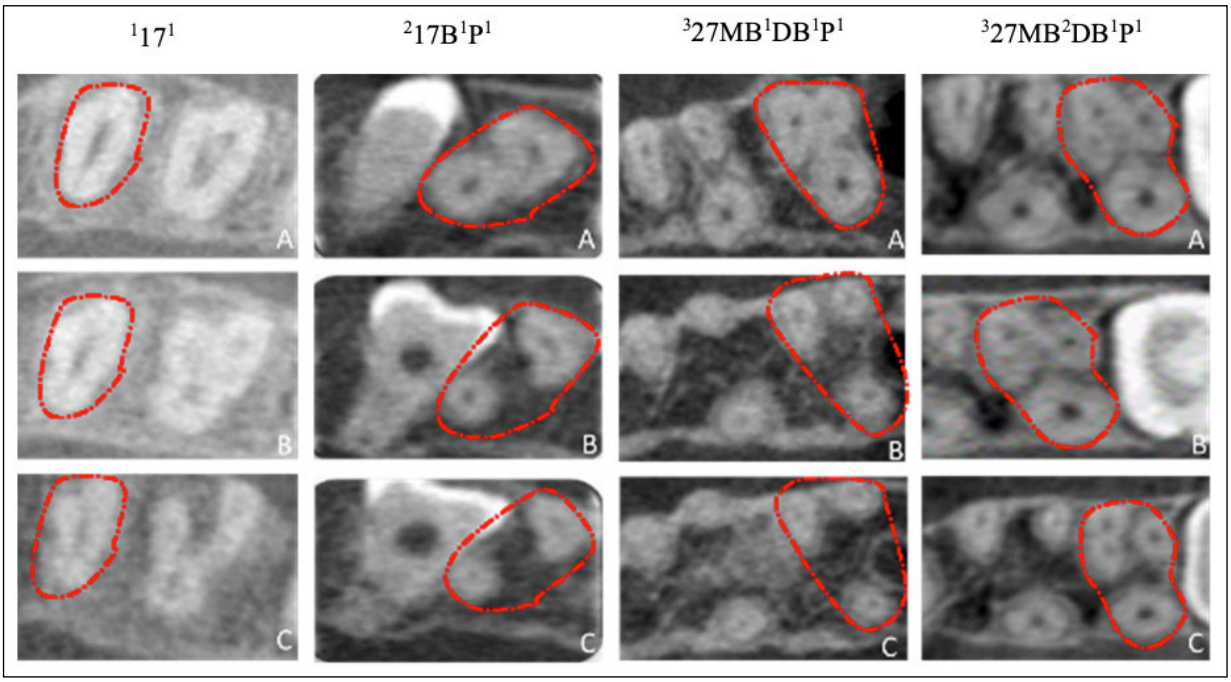

Figure 3. CBCT axial view in coronal (A), Middle (B) and apical (C) thirds showing root canal morphology according to Ahmed et al[17] classification for one, two and three rooted maxillary molars.

Discussion

The success of root canal treatment is dependent on ensuring that all the intricate details associated with it are meticulously followed. Failure to locate all canals could have a negative effect on the treatment as it may lead to initiation or continuation of periapical pathology[18]. Missed canals were the main reason for patients reporting back for nonsurgical root canal treatment as reported by Witherspoon et

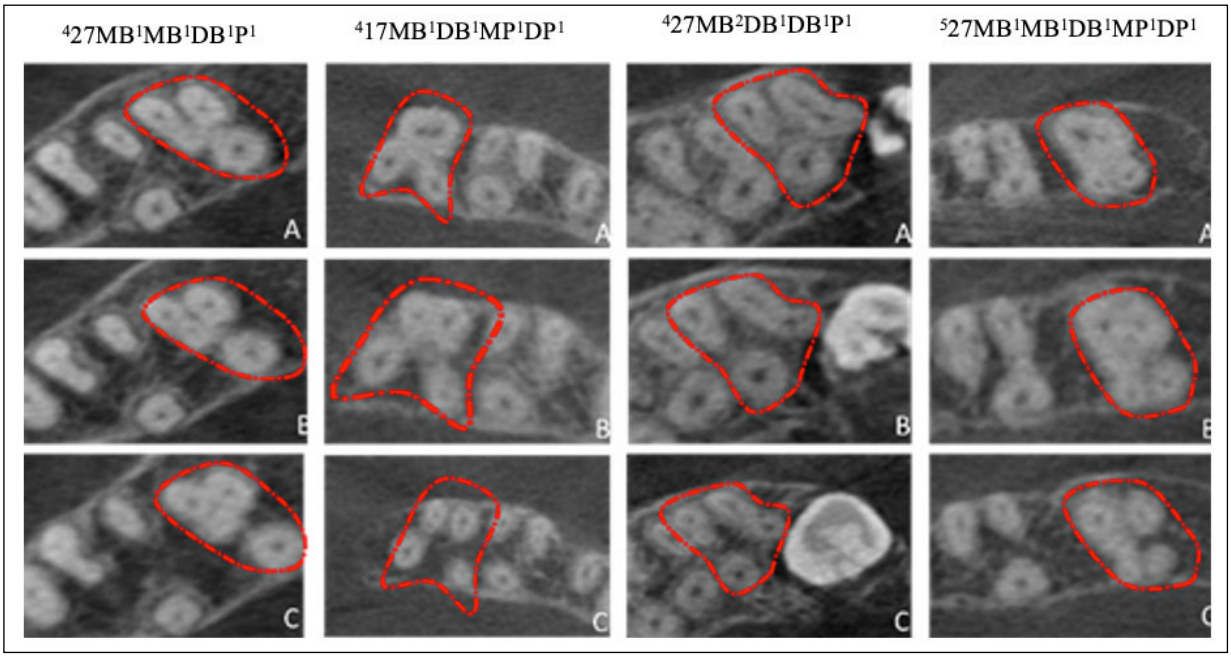

Figure 4. CBCT axial view in coronal (A), middle (B) and apical (C) thirds showing root canal morphology according to Ahmed et al[17] classification for four and five rooted maxillary molars.

Table VI. Gender wise distribution of canals according to Vertucci classification in the mesiobuccal root of maxillary molars.

Teeth	Symmetry regarding the number of roots				Symmetry regarding the number of canals				Gender based symmetry regarding the number of canals				
	n	NS	S	%	n	NS	S	%	G	n	NS	S	%
1st Molars	323	0	323	100	323	25	298	92.2	M	175	15	160	91.4
									F	148	10	138	93.2
2nd Molars	307	11	296	96.4	307	50	257	83.7	M	177	21	156	88.1
									F	130	29	101	77.7
	% of Agree: 98.4; Cohen's k:0.96				% of Agree: 80.95; Cohen's k: 0.61;				% of Agree: 80.95; Cohen's k: 0.61;				

Note: n, number of scans showing bilateral molars; NS, not symmetrical; S, symmetrical; G, gender; M, males; F, females.

al[19]. Moreover, the bacteria residing in such canals could also result in persistence of symptoms[20].

The molars are the commonest teeth undergoing root canal treatment, with the maxillary molars occupying the third and fourth positions[21]. Many variations in canal anatomy are encountered with the maxillary molars, especially in the MBR[22]. The routine use of CBCT in detecting the canal anatomy cannot be justified due to higher levels of radiation and the clinical success achieved by the dental operating microscopes due to their enhanced magnification and illumination[23]. CBCT, though, has a role in detecting aberrant canal anatomies, C-shaped root canals, unusual root formations, and cases where endodontic treatment has been performed to a good standard and has still failed[24].

All the MFM's evaluated in our study had three roots irrespective of gender. Similar findings were found in studies conducted among Chinese, Polish, Iranian, Thai, Burmese and Kuwaiti populations[4,12,25-29]. Our findings were also comparable with recent studies among Saudi and Thai population which showed 99.7% and 99.8% of first molars with three roots, respectively[30,21]. Slightly lower percentages were reported in Brazilian, Korean, Chinese, Taiwanese, and Emirati populations[3,10,11,15,31]. Some of the variations seen in other studies, like a single root, two roots and four roots in MFM's, were not found in this study[10,31,32].

The number of roots in MSM's was more variable in our study, although three rooted second molars were the most common finding in up to 95.5% of the teeth. These observations were comparable to results from India, Poland and Taiwan[7,12,15]. Similar results were also seen in a previously published study in a mixed population residing in Saudi Arabia comprising of Saudis and non-Saudis[33]. Other variations among roots of MSM's in our study included teeth with a single root, two roots, four roots and five roots. One and two rooted variations were also reported in many other studies[4,10,11,16]. Four rooted MSM's were reported in studies from Korea, China, Thailand, and Saudi Arabia[10,11,16,33]. The incidence of five rooted MSM's was a rarity, previously only reported in Taiwanese population[15].

Regarding the root and root canal configurations in MFM's, three roots with four root canals (3R4C) were the most common finding in this study. It was found in 85.6% of the scans. The remaining first molars had three roots and three canals (3R3C) configuration in 14.4% of the scans, similar to the results seen in other previous studies[10,12]. Contrasting results were reported in a previous study among the Saudi population by Nazhan et al[34] who reported the presence of 3R4C in only 23.3% of the first molars. However, using a similar radiographic evaluation method in Saudi population, Fawzan et al[9] reported the incidence of 3R4C in 51.3% of the first molars. When CBCT was used as an imaging modality to evaluate first molars in Saudi's, Al-Shehri et al[30] found the incidence of 3R4C in nearly 55.6% of the scans. Variations among same populations were also reported in Chinese and Thai regions which emphasizes the importance of conducting multicenter and multiregional studies within the same community for a more accurate representation of the communities' internal canal anatomy[4,6,11,16,27].

All of the extra canals in the present study among MFM's were present in the MBR. The first molars disto-buccal root (DBR) and the palatal root (PR) had single canals in all of the scans. Regarding canal configuration, Type I VC was seen in 100% of PR's and DBR's. Similar results were seen in most of the studies conducted, which tend to show a Type I VC percentage ranging from 98-100%[4,10,27,30]. However, Al-Mheiri et al[31] in a study on the Emirati population, reported Type II VC of 1.2% and 2% in palatal and dis-

to-buccal canals, respectively. Type II VC was also observed in the palatal root of maxillary first molars among Indian patients, as reported by Poorni et al[35].

Canals in the MBR of the MFM's, as in most other studies had greater variations in configuration[12]. Type II VC in the MBR was most commonly found in this study, followed by Type IV, Type I and Type III. An identical morphology sequence was seen in Spanish population, except for Type III VC[36]. The Emirati study showed Type II, Type I, Type IV and Type III VC sequences[31]. However, Korean, Indian, Qatari and Brazilian studies reported Type IV VC more frequently than Type II[7,10,37,38]. In the Saudi population, a previous study reported the presence of Type II and Type IV VC in maxillary molars[9], and a more recent study by Al-shehri et al[30] reported the presence of all the types of VC in MFM's except Type VIII. The sequence in his study according to the percentages were Type I (35.1%), Type IV (33.3%), Type II (24.4%), Type III (3.6%), Type V (1.8%), Type VI (1.2%), Type VII (0.3%) and a newer variation (0.3%). In the present study, Type II VC was seen in 51.65%, similar percentages of Type II canal configuration were reported in Spanish and Emirati population[31,36]. Type IV VC in MFM's in this study was seen in 32.2%, which was similar to findings before in Saudi's (33.3%)[30], higher than those reported in Emirati's (15.3%)[31], and Spanish (23.2%)[36] but lower than those seen in Indian (38.6%)[7] and Korean (40.6%)[10] populations. The presence of Type I VC in the present study was seen in 15.25%, which was similar to the Spanish (13.8%)[36], and Emirati population (19.9%)[31], but lower than the Korean (36.4%)[10] and Saudi population (35.1%)[30]. The presence of Type III VC was the lowest in this study, around 0.9%. This finding was lower than that seen in Emiratis (6%)[31], and the previous study on Saudi's (3.6%)[30].

The MSM's in this study was found to have more variations in canal morphologies following previous studies[4,10,12]. 3R3C was seen in nearly half [51.95% (52.8% R and 51.1% L)] of the observed scans similar to studies in Taiwan and Brazil[1,15]. Much higher percentages of 3R3C configuration in MSM's was reported from studies in China (78%) and Poland (70%)[6,12]. Al Fawzan et al[9] also reported higher percentages (80.2%) of 3R3C configuration in second molars. Such differences could be because of different evaluation methods used in their study. 3R4C morphologies in the present study were seen in 43.55% of the MSM's, which is nearly similar to the results in studies conducted in Brazil, Korea, and Taiwan[1,10,15]. Lower percentages of 3R4C were seen in Chinese 22%, Saudi Arabian 19.8% and Polish 23.2% populations[6,9,12].

Four maxillary second molars (0.6%) two on either side were identified as having 1R1C configuration similar to results previously reported in Taiwan (0.56%)[15], Thai (1.5%)[16], and Polish (1%)[12] populations. Slightly higher numbers were observed in Korean (3.8%)[10] and Chinese population (5.7%)[4]. Furthermore, one tooth (0.3%) in the present study was identified to have a 1R2C configuration similar to what was observed before in Indian (0.9%)[7], Korean (1%)[10], Taiwanese (0.89%)[20], Thai (1.5%)[16], and Chinese (4.2%)[4] populations.

In the present study, nine MSM's (1.35%) were observed to have a 2R2C configuration which was previously observed in root canal morphological studies on second molars in Indian (1.9%)[7], Taiwanese (4.58%)[15], Thai (5.2%)[16], Chinese (8%)[4], and Korean (7%)[10] populations. Additionally, the 2R3C root and canal configuration was observed in nine teeth, ensuing 1.35% of all the MSM's. Comparable findings were observed in Korean (2.8%)[10], Taiwanese (0.67%)[15], and Thai (3.5%)[16] populations.

Five MSM's (0.75%) in this study were identified to have a 4R4C configuration with a single canal in all four roots. The variation in this configuration was seen as an extra palatal root and canal in two teeth and an extra buccal root and canal in one tooth on the right, and an extra buccal root in two teeth on the left. Another variation in the four rooted MSM's in this study was identifying one tooth (0.3%) with 4R5C configuration having an additional root and canal in the DBR, two canals in the MBR and an additional palatal root and canal. Previously the presence of 4R4C in MSM's with the extra root and canal being the palatal was observed in Korean (1.82%)[10], Chinese (1.2%)[11], Indian (1.1%)[39], and Taiwanese (0.78%)[15] populations. In Saudi Arabia, a clinical retreatment case of 4R4C in MSM's with extra palatal root and canal was reported by Alanezi and Ahmed and Ahmad[40] in 2015.

A different variant of MSM's with 5R5C configuration (0.3%) was also observed in this study, similar to the observation in the Taiwanese population with the extra roots being the second palatal and an extra root on the buccal side[15]. The presence of so many root and canal configurations variants indicate that the maxillary second molars present a more complex root canal system than first molars.

All the PR's and DBR's of the MSM's in the present study were observed to have a Type I VC. Three MSM's with extra palatal roots and one

tooth with extra DBR seen in this study also had Type I VC. Similarly, the DBR's also had Type I VC in 99.7% of the population. Only one tooth with a 4R5C configuration presented a Type IV VC in the DBR. DBR and PR's with Type II, Type IV and Type V VC configurations were observed in Thai populations[16]. Two DBR's were observed in the Korean population[10]. Two palatal roots in MSM's were previously observed in Korean, Indian and Saudi population[10,39,40]. In the MBR of the MSM's, the following variations were observed: 55.15% of the canals had a Type I VC, 24.35% of the canals had a Type IV VC and 20.6% of the canals had a Type II VC. A previous Saudi Arabian study also reported the presence of similar VC in their study[9]. In Korean population, all the types of VC except Type VII and VIII were reported in MSM's[10]. However, in the Chinese population, the presence of all the types of VC was observed[11].

The presence of a second canal (MB_2) in the MBR's of the maxillary molars have been long recognized, and numerous studies indicate its occurrence ranges from 48-97% in the MFM's as reported by Martins et al[32], in a worldwide observation and also reported in numerous other studies[1,4,6,12,15,16]. In the MSM's its incidence has been known to range from 22-48%[4,8,12]. In the present study, the MB_2 canal was observed around 85.6% in the MFM's and 43.6% in the MSM's. The results were much higher than those obtained in other studies in the Saudi population, where a range of 23.7- 70.6% had been reported in the past in MFM's and 19.82% had been reported in MSM's[9,30,34,41]. Such differences could be because of different evaluation methods used in these studies. Alamri et al[33] in their study also noted the percentage of MB_2 in Saudi population was comparatively higher than other populations. Moreover, a more recent study by Fawzan et al[42], using micro-CT to evaluate the presence of extra canals in the MBR's of maxillary molars indicated that MB_2 was present in 97% of the MFM's had 93% in MSM's. The authors highlighted that although Micro-CT is considered a gold standard for lab-based visualization and internal anatomy evaluation, CBCT is still more feasible when different parameters like age and gender are evaluated.

Bilateral symmetry regarding the roots of MFM's was 100%, and in MSM's was 96.4%. The inter-rater reliability was 98.4, giving an almost perfect Cohen's K value of 0.96 according to the guidelines of interpretation of Cohen's kappa results as given by Landis and Koch[43].

Regarding symmetry of root canals, the MFM's were detected with symmetrical canal configurations bilaterally in 92.2% of the scans, whereas the MSM's showed bilateral symmetrical configuration of root canals in 83.7%. The inter-observer reliability was 80.95 with a Cohen's K value of 0.61, which shows a substantial agreement following the same guidelines. Previous studies worldwide have shown bilateral symmetry in MFM's to range from 71.1-87.36% and in MSM's from 70.8-82.3%[11,15,39]. Two studies focused on the bilateral occurrence of MB_2 canals and showed the high tendency of its occurrence bilaterally[10,16].

Conclusions

Within the limits of this study, it was concluded that the first and second maxillary molar teeth in the Saudi population usually had three separate roots. Type II was the most common canal configuration in bilateral first molars and Type I in second molars. Additionally, a higher amount of symmetry was seen in the root and canals bilaterally in both the molars. Additional roots and several variations in canal configurations are seen more frequently in the second molars, requiring the clinicians to be more prudent when performing root canal treatment to reach the desired success. CBCT as a means of diagnosis can be helpful if the performed treatment is not successful and in cases of suspicion of missed anatomy.

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Conflict of Interests

The authors declare that they have no conflict of interest.

Informed Consent

Obtained.

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References

1) Santos-Junior AO, De Castro Pinto L, Mateo-Castillo JF, Pinheiro CR. Success or failure of endodontic treatments: a retrospective study. J Conserv Dent 2019; 22: 129-132.
2) Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endodontic Topics 2005; 10: 3-29.
3) Silva EJ, Nejaim Y, Silva AI, Haiter-Neto F, Zaia AA, Cohenca N. Evaluation of root canal configuration of maxillary molars in a Brazilian population using cone-beam computed tomographic imaging: an in vivo study. J Endod 2014; 40: 173-176.
4) Zhang R, Yang H, Yu X, Wang H, Hu T, Dummer PM. Use of CBCT to identify the morphology of maxillary permanent molar teeth in a Chinese subpopulation. Int Endod J 2011; 44: 162-169.
5) Wu D, Zhang G, Liang R, Zhou G, Wu Y, Sun C, Fan W. Root and canal morphology of maxillary second molars by cone-beam computed tomography in a native Chinese population. J Int Med Res 2017; 45: 830-842.
6) Zheng QH, Wang Y, Zhou XD, Wang Q, Zheng GN, Huang DM. A cone-beam computed tomography study of maxillary first permanent molar root and canal morphology in a Chinese population. J Endod 2010; 36: 1480-1484.
7) Neelkantan P, Subbarao C, Ahuja R, Subbarao CV, Gutmann JL. Cone-beam computed tomography study of root and canal morphology of maxillary first and second molars in an Indian population. J Endod 2010; 36: 1622-1627.
8) Lee JH, Kim KD, Lee JK, Park W, Joeng JS, Lee Y, Gu Y, Chang SW, Son WJ, Lee WC, Baek SH, Bae KS, Kum KY. Mesiobuccal root canal anatomy of Korean maxillary first and second molars by cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011; 11: 785-791.
9) Al-Fouzan KS, Ounis HF, Merdad K, Al-Hezaimi K. Incidence of canal systems in the mesio-buccal roots of maxillary first and second molars in Saudi Arabian population. Aust Endod J 2013; 39: 98-101.
10) Kim Y, Lee SJ, Woo J. Morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a Korean population: variations in the number of roots and canals and the incidence of fusion. J Endod 2012; 38: 1063-1068.
11) Tian XM, Yang XW, Qian L, Wei B, Gong Y. Analysis of the Root and Canal Morphologies in Maxillary First and Second Molars in a Chinese Population Using Cone-beam Computed Tomography. J Endod 2016; 42: 696-701.
12) Olczak K, Pawlicka H. The morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a polish population. BMC Med Imaging 2017; 17: 68.
13) Weine FS, Healey HJ, Gerstein H, Evanson L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg Oral Med Oral Pathol 1969; 28: 419-425.
14) Park JW, Lee JK, Ha BH, Choi JH, Perinpanayagam H. Three-dimensional analysis of maxillary first molar mesiobuccal root canal configuration and curvature using micro-computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108: 437-442.
15) Tzeng LT, Chang MC, Chang SH, Huang CC, Chen YJ, Jeng JH. Analysis of root canal system of maxillary first and second molars and their correlations by cone beam computed tomography. J Formos Med Assoc 2020; 119: 968-973.
16) Ratanajirasut R, Panichuttra A, Panmekiate S. A cone-beam computed tomographic study of root and canal morphology of maxillary first and second permanent molars in a Thai Population. J Endod 2018; 44: 56-61.
17) Ahmed HMA, Versiani MA, De-Deus G, Dummer PMH. A new system for classifying root and root canal morphology. Int Endod J 2017; 50: 761-770.
18) Baruwa AO, Martins JNR, Meirinhos J, Pereira JG, Gouveia J, Quaresma SA, Monroe, Ginjeira A. The influence of missed canals on the prevalence of periapical lesions in endodontically treated teeth: A cross-sectional study. J Endod 2020; 46: 34-39.
19) Witherspoon DE, Small JC, Regan JD. Missed canal systems are the most likely basis for endodontic retreatment of molars. Tex Dent J 2013; 130: 127-139.
20) Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. Eur J Dent 2016; 10: 144-147.
21) Yousuf W, Khan M, Mehdi H. Endodontic procedural errors: frequency, type of error, and the most frequently treated tooth. Int J Dent 2015; 2015: 673914.
22) Cleghorn BM, Christie WH, Dong CC. Root and root canal morphology of the human permanent maxillary first molar: a literature review. J Endod 2006; 32: 813-821.
23) Kumar R., Khambete N. Surgical operating microscopes in Endodontics. Enlarged vision and possibilities. Int J Stomat Res 2013; 2: 11-15.
24) Davies A, Mannocci F, Mitchell P, Andiappan M, Patel S. The detection of periapical pathoses in root filled teeth using single and parallax periapical radiographs versus cone beam computed tomography - a clinical study. Int Endod J 2015; 48: 582-592.
25) Naseri M, Safi Y, Akbarzadeh BA, Khayat A, Eftekhar L. Survey of anatomy and root canal morphology of maxillary first molars regarding age and gender in an Iranian population using cone-beam computed tomography. Iran Endod J 2016; 11: 298-303.
26) Naseri M, Mozayeni MA, Safi Y, Heidarnia M, Baghban AA, Norouzi N. Root canal morphology of maxillary second molars according to age and gender in a selected Iranian population: a cone-beam computed tomography evaluation. Iran Endod J 2018; 13: 373-380.

27) Alavi AM, Opasanon A, Ng YL, Gulabivala K. Root and canal morphology of Thai maxillary molars. Int Endod J 2002; 35: 478-485.

28) Ng YL, Aung TH, Alavi A, Gulabivala K. Root and canal morphology of Burmese maxillary molars. Int Endod J 2001; 34: 620-630.

29) Pattanshetti N, Gaidhane M, Al Kandari AM. Root and canal morphology of the mesiobuccal and distal roots of permanent first molars in a Kuwait population-a clinical study. Int Endod J 2008; 41: 755-762.

30) Al-Shehri S, Al-Nazhan S, Shoukry S, AL-Shwaimi E, Al-Sadhan R. AL-Shemmery B. Root and canal configuration of the maxillary first molar in a Saudi subpopulation: a cone-beam computed tomography study. Saudi Endod J 2017; 7: 69-75.

31) Al Mheiri E, Chaudhry J, Abdo S, El Abed R, Khamis AH, Jamal M. Evaluation of root and canal morphology of maxillary permanent first molars in an Emirati population; a cone-beam computed tomography study. BMC Oral Health 2020; 20: 274.

32) Martins JNR, Alkhawas MAM, Altaki Z, Bellardini G, Berti L, Boveda C, Chaniotis A, Flynn D, Gonzalez JA. Worldwide analyses of maxillary first molar second mesiobuccal prevalence: A multicenter cone-beam computed tomographic study. J Endod 2018; 44: 1641-1649.

33) Alamri HM, Mirza MB, Riyahi AM, Alharbi F, Aljarbou F. Root canal morphology of maxillary second molars in a Saudi sub-population: A cone beam computed tomography study. Saudi Dent J 2020; 32: 250-254.

34) Al Nazhan S. The prevalence of two canals in mesial root of endodontically treated maxillary first molars among a Saudi Arabian sub population. Saudi Dent J 2005; 17: 24-28.

35) Poorni S, Kumar A, Indira R. Maxillary first molar with aberrant canal configuration: a report of 3 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 106: e53-55.

36) Pérez-Heredia M, Ferrer-Luque CM, Bravo M, Castelo-Baz P, Ruíz-Piñón M, Baca P. Cone-beam computed tomographic study of root anatomy and canal configuration of molars in a Spanish population. J Endod 2017; 43: 1511-1516.

37) Mohammed Alobaid M, Alsheeb FA. Root canal morphology of maxillary first and second molars in a Qatari population: A cone beam computed tomography study. Eur Dent Res Biomater J 2021; 2: 34-38.

38) Magalhaes J, Veloza C, Albuquerque D, Soares C, Oliveria H, Pontual ML, Perez FR, Pontual A. Morphological study of root canals of maxillary molars by cone beam computed tomography. Sci. World J 2022; 2022: 4766305.

39) Felsypremila G, Vinothkumar TS, Kandaswamy D. Anatomic symmetry of root and root canal morphology of posterior teeth in Indian subpopulation using cone beam computed tomography: A retrospective study. Eur J Dent 2015; 9: 500-507.

40) Alenazy MS, Ahmad I. A case report: Double palatal roots in maxillary second molars: A case report and literature review. Saudi Endod J 2015; 5: 56-60.

41) Alrahabi M, Sohail Zafar M. Evaluation of root canal morphology of maxillary molars using cone beam computed tomography. Pak J Med Sci 2015; 31: 426-430.

42) Alfouzan K, Alfadley A, Alkadi L, AlhezamA, Jamleh A. Detecting the second mesiobuccal canal in maxillary molars in a Saudi Arabian population: a micro-CT study. Scanning 2019; 2019: 9568307.

43) Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159-174.