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Relationship between root canal merging and presence of C-shaped canal in fused rooted maxillary molar teeth

Relação entre a fusão do canal radicular e a presença de canal em forma de C em dentes molares maxilares fundidos e enraizados

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ABSTRACT

Objective: This study aimed to evaluate the prevalence of root fusion and the incidence of C-shaped canals in maxillary first molar (MFM) and maxillary second molar (MSM) teeth using cone-beam computed tomography. **Material and Methods:** In this study, a total of 1233 MFMs and 1406 MSMs from 802 patients were analyzed. First, the number of fused rooted teeth and the type of root fusion were determined. Subsequently, incidence and number of C-shaped canals were ascertained according to the type of fusion, location, position, and level of canal merging in teeth with fused roots. Six types were established according to the C-shape configurations observed. Presence of root fusion and the C-shaped canal according to gender, age, and tooth position were evaluated by chi-square test. Values with $p < 0.05$ were considered significant in statistical tests. **Results:** The incidence of fusion in the MFM and MSM teeth was 6.16% and 22.40%, respectively. Only three MFMs (0.24%) and 3.77% of the MSMs had C-shaped canals. While the incidence of fusion was higher in women ($p < 0.05$), the C-shaped morphology was not affected by sex ($p > 0.05$). Individuals over the age of 50 years had a lower incidence of C-shaped canals ($p < 0.05$). **Conclusion:** C-shaped canal morphology was more commonly associated with complex types of root fusion involving three roots; 16.83% of MSMs with fused roots had C-shaped canals.

KEYWORDS

Canal merging; Cone-beam computed tomography; C-shaped root canal; Root canal anatomy; Root fusion.

RESUMO

Objetivo: o objetivo deste estudo foi avaliar a prevalência de fusão radicular e a incidência de canais em C nos dentes do primeiro molar superior (MFM) e do segundo molar superior (MSM) por meio da tomografia computadorizada de feixe cônico. **Material e Métodos:** Neste estudo, um total de 1233 MFMs e 1406 MSMs de 802 pacientes foram analisados. Primeiro, o número de dentes com raízes fundidas e o tipo de fusão radicular foram determinados. Posteriormente, a incidência e o número de canais em forma de C foram verificados de acordo com o tipo de fusão, localização, posição e nível de fusão do canal nos dentes com raízes fundidas. Seis tipos foram estabelecidos de acordo com as configurações em forma de C observadas. A presença de fusão radicular e do canal em C de acordo com sexo, idade e posição dentária foram avaliadas pelo teste do qui-quadrado. Valores com $p < 0,05$ foram considerados significativos nos testes estatísticos. Resultados: A incidência de fusão nos dentes MFM e MSM foi de 6,16% e 22,40%, respectivamente. Apenas três MFMs (0,24%) e 3,77% dos MSMs tinham canais em forma de C. Enquanto a incidência de fusão foi maior em mulheres ($p < 0,05$), a morfologia em forma de C não foi afetada pelo sexo ($p > 0,05$). Indivíduos com mais de 50 anos apresentaram menor incidência de canais em C ($p < 0,05$). **Conclusão:** a morfologia do canal em forma de C foi mais comumente associada a tipos complexos de fusão radicular envolvendo três raízes; 16,83% dos HSH com raízes fundidas tinham canais em forma de C.

PALAVRAS-CHAVE

Fusão de canais; Tomografia computadorizada de feixe cônico; Canal radicular em forma de C; Anatomia do canal radicular; Fusão de raízes.

INTRODUCTION

The C-shaped canal configuration is an anatomical variation characterized by the presence of a fin or web between the canals, typically seen in teeth with root fusion [1]. These canal variations play a significant role in the location of orifices, procedures for cleaning, shaping and filling, restoration of teeth, and consequent endodontic treatment success [2]. C-shaped canal systems have irregular zones between the main canals. If the root canal treatment is not successfully performed, these zones can host microorganisms and cause persistent intraradicular infection. The presence of C-shaped canals in teeth requires different endodontic treatment regimens than teeth with normal anatomy [3].

This canal configuration, seen especially in mandibular second molars, has also been reported in mandibular first molars, premolars and maxillary molars (MM) [4]. After Cooke and Cox [5] first identified the clinical significance of C-shaped canals in mandibular molars, Newton and McDonald [6] reported a C-shaped configuration in the maxillary first molar (MFM) resulting from the fusion of the distobuccal (DB) and palatal (P) canals. Although much research has been done on C-shaped mandibular molars [3,7]; this anatomical feature has only been mentioned in case reports [8,9] and has been investigated in a limited number of in vivo studies for many years in MMs [10,11]. Furthermore, some of these studies did not identify the criterion for the C-shape [10]; others only evaluated the fusion between the DB and the P root [11]. Therefore, a C-shaped canal configuration was either not identified [10] or reported at very low percentages (0.09% for the MFM) [11].

Although an attempt may be made to assess the characteristics of the canal systems with intraoral radiographs before the procedure, it can be challenging to detect fusion and the presence of C-shaped canals in fused rooted MMs. Recently, cone-beam computed tomography (CBCT) has become a popular imaging technique in endodontics and general dentistry [12]. A three-dimensional examination of the root and canal morphology facilitates non-invasive evaluation of different population groups with larger sample sizes [12]. However, there are limited studies on C-shaped root canals in the MMs [4,13,14]. It is known that the incidence of C-shaped anatomy can vary between different geographical populations [15]. Moreover, no study has investigated this canal variation in the Turkish population.

This study aimed to investigate the prevalence of root fusion and C-shaped canal in maxillary molar teeth, analyze the factors affecting these anatomical features and examine the relationship between the situations of root canal merging.

MATERIAL AND METHODS

The study protocol was submitted to the Akdeniz University Medical Ethics Committee to obtain approval before research (process number 70904504/249). A total of 802 CBCT images were obtained from a private dental centre data pool for diagnosis and treatment planning, and no additional CBCT images were used for the study. The imaging objectives were dental implant assessment, advanced surgical planning, endodontic evaluation and comprehensive treatment planning.

Patients over 18 years of age with at least one MM were included; subjects with uncertain tooth numbers and images of poor quality were excluded. Other exclusion criteria were as follows: endodontically treated teeth, teeth restored with posts, and teeth with metallic restorations, periapical pathology, incomplete root development or resorption. The device used for imaging was Sirona Orthophos XG3D (Sirona Dental Systems GmbH, Bensheim, Germany). The following parameters were assigned: 5 kV, 6.0 mA, 8 × 8 image area and 0.160-mm^3 voxel size. The images were analyzed in the axial, sagittal and coronal planes with the Sidexis software (Sirona) by a single observer, who was experienced and well trained in CBCT imaging.

First, the number of fused rooted teeth and the type of root fusion were determined in the MFM and the maxillary second molar (MSM) teeth (Figure 1) [14]. The types of fusion (F-type) were classified as follows: F-type 1: fusion of mesiobuccal (MB)-DB roots; F-type 2: MB root fused with the P root; F-type 3: fusion of DB-P roots; F-type 4: in addition to a fusion of MB and DB roots, a fusion between the MB or DB root and the P root; F-type 5: P root fused with MB and DB roots; F-type 6: cone-shaped structure formed between fused buccal (B) roots and the P root;

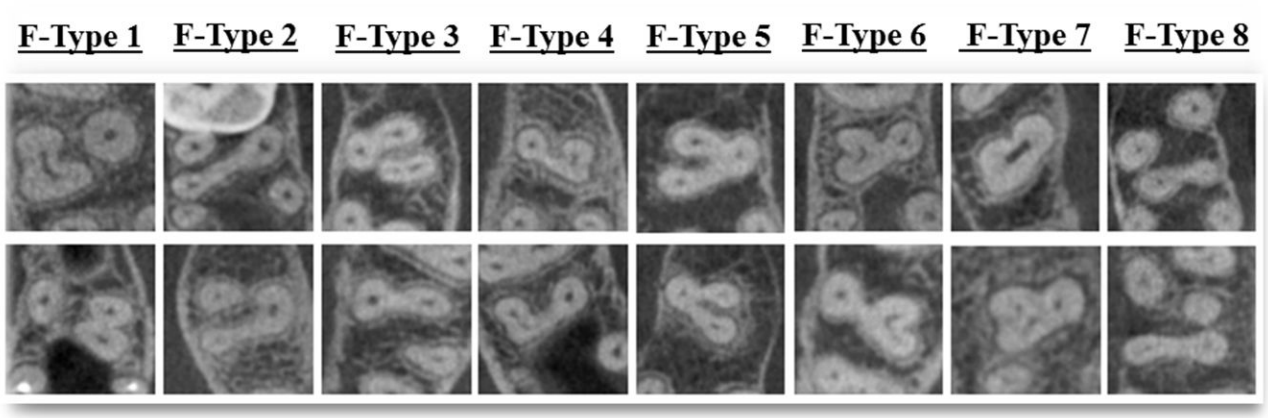

Figure 1 - Examples of fusion types.

F-type 7: three roots fused to form a single mass; F-type 8: root fusion between four-rooted teeth.

The criterion to determine fused roots was as follows: the ratio of the distance from the cementoenamel junction to the furcation or root fusion and the distance from the cementoenamel junction to the root apex was more than 70% [16]. Subsequently, the fused rooted teeth were examined for the following features:

1. Presence of merged canals (no merging, 2-canal merging or multiple canal merging), canal merging positions (the specific canals that have merged) and merging levels (coronal, middle, apical thirds or combinations of these);
2. Presence of fusion according to gender, age group and tooth position;
3. Prevalence and types of C-shaped canals (C-type);
4. Prevalence of C-shaped canals according to the type of fusion, location of canal merging (no merging, 2-canal merging or multiple canal merging) and merging position;
5. Prevalence of C-shaped canals according to gender, age group and tooth position.

A modification of the classification used for C-shaped mandibular molars in axial section in a previous study was selected to classify the upper C-shaped canal configuration (UC) [13];

a) Category 1 (UC1): pronounced canal system that continues without interruption between the canals;

b) Category 2 (UC2): large isthmus between two main canals;

c) Category 3 (UC3): two independent canals;

d) Category 4 (UC4): one round or oval canal;

e) Category 5 (UC5): no observed canal lumen.

The root was divided into three equal parts along the root length: coronal, middle and apical. The changes in the UC configurations were analysed by examining the cross-sections from the midpoints of these thirds.

The presence of a C-shaped canal in a fused rooted tooth was identified when at least two roots were fused, and either two main canals were connected by a continuous wide C-shaped canal system, or a wide isthmus was present between the canals along a third of the root (UC1 and UC2).

Based upon the observations, six types were determined according to the C-shape configurations (Figure 2). The classification system used by Martins et al. [13] was largely appropriate for this study, but was modified with the creation of a new category to accommodate for all types observed. The categories were therefore defined as follows:

1- C-type A: semilunar connection between fused MB and P canals;

2- C-type B: semilunar buccal root canal system between the MB and DB root canals with its concavity angled towards the buccal or the palatal;

3- C-type C: presence of a C-shaped canal between the DB and P canals;

4- C-type D: canal morphology assumes the shape of the letter 'Y' between three canals;

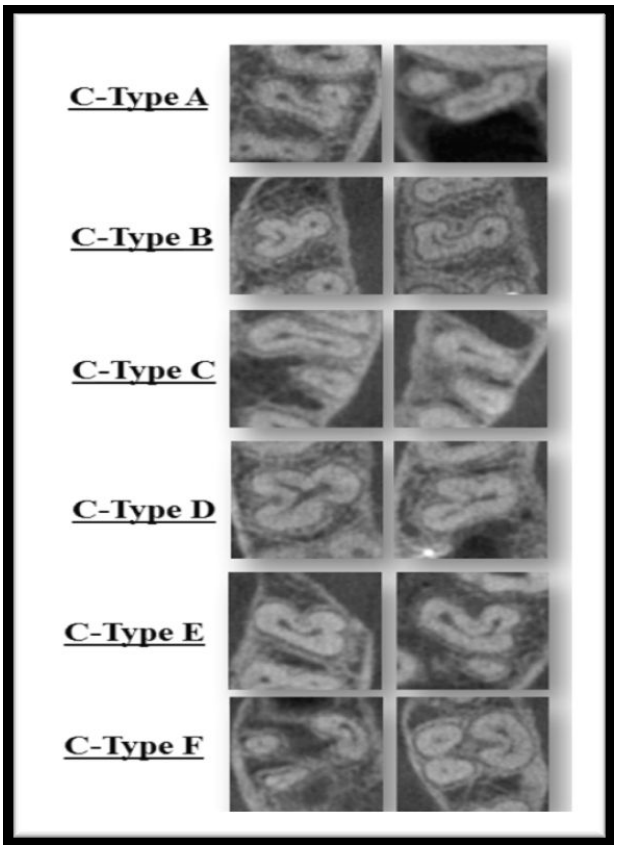

Figure 2 - Examples of C-shaped types.

5- C-type E: C-shaped canal that resembles mandibular C-shape anatomy in teeth where three roots are fused; straight lines between the B and P canals in the same direction or "C" letter-shaped anatomy between the B and P canals;

6- C-type F: presence of a large semilunar P canal between two fused P roots.

For intra-rater reliability, one month later, 20% of the samples were re-examined, and the degree of agreement was evaluated with the kappa test. This time period was chosen in order to make an unbiased observation, taking into account the memory factor in recalling the findings of the first observation. Data were analyzed using the SPSS 22.0 package program (IBM SPSS Statistics, Chicago, IL). Chi-square and Fisher's exact tests were used to assess associations between variables such as gender, age group, and tooth position. Z test was used for percentages between independent groups. Values with $p < 0.05$ were considered significant.

RESULTS

In this study, the images of 403 females (50.2%) and 399 males (49.8%) were examined (mean age = 36.4 ± 11.1 years; min: 18, max: 72). A total of 1233 maxillary first molars and 1406 maxillary second molars were analyzed. The agreement between both observations was 79%, with a ± 14.7 asymptotic error.

Prevalence of fusion, root canal merging, merging positions, and merging levels

The incidence of fusion in MFMs was 6.16% ($n = 76$) and 22.40% ($n = 315$) in MSMs with a significant difference ($p < 0.05$). The prevalence of the types of fusion in MFMs and MSMs and the location, position and merging levels in fused rooted teeth are listed in Tables I and II, respectively. The prevalence of fusion was higher in females in both teeth groups ($p = 0.005$ and $p < 0.001$, respectively) (Table III). There was no difference according to age group and tooth position ($p > 0.05$) (Table III).

C-shaped prevalence according to fusion types, location and position of canal merging

The prevalence of C-shaped canal types for MFMs and MSMs are listed in Table IV. Only three MFMs showed the presence of C-shaped canals, with a prevalence of 3.95% in fused rooted teeth and 0.24% in all MFMs; these three teeth showed C-type C configuration (DB-P) and F-type 3 fusion (DB-P). Due to the low number of MFMs, no further analysis was performed.

A total of 53 MSMs had C-shaped canals: 16.83% among teeth with fused roots and 3.77% among all MSMs. C-type B (MB-DB) was the most common C-shaped canal configuration. The number and percentage of C-shaped canals among fusion types are listed in Table V. A higher proportion of C-shaped canals was observed in teeth with three fused roots and complex configurations such as F-types 6 and 7 ($p < 0.001$). The number and percentage of C-shaped canals according to the location of the root canal and the merging position in fused rooted teeth are shown in Table V. C-shape was more commonly found in teeth with multiple canal merging ($p < 0.001$), with a higher incidence in teeth with canal merging between the P roots, MB-P and MB-DB-P roots ($p < 0.001$). The percentage of C-shaped fused rooted teeth was not affected by gender, age group or tooth position (Table VI; $p > 0.05$). However, if the cases were classified into two age groups of under 50 years and 50 years or more, the percentage was lower in the group of under

Table I - Number and percentage of fusion types and locations, positions and levels of canal merging according to fusion types in maxillary first molars

	Types of root fusion, n (%)						
	Not	F-Type 1	F-Type 2	F-Type 3	F-Type 4	F-Type 5	F-Type 7
Presence of root fusion	1157 (93.84)	8 (0.65)	6 (0.49)	57 (4.62)	2 (0.16)	2 (0.16)	1 (0.08)
Canal merging situation							
3 non-merging canal	1175 (95.3)	-	6 (0.49)	50 (4.06)	-	2 (0.16)	-
2 merging canal	1216 (98.62)	8 (0.65)	-	7 (0.57)	2 (0.16)	-	-
Multiple merging canal	1232 (99.92)	-	-	-	-	-	1 (0.08)
Canal merging position							
MB-DB	1223 (99.19)	8 (0.65)	-	-	2 (0.16)	-	-
DB-P	1226 (99.43)	-	-	7 (0.57)	-	-	-
MB-DB-P	1232 (99.92)	-	-	-	-	-	1 (0.08)
Canal merging level							
Coronal	1232 (99.92)	-	-	-	1 (0.08)	-	-
Middle	1232 (99.92)	-	-	1 (0.08)	-	-	-
Apical	1228 (99.59)	1 (0.08)	-	4 (0.32)	-	-	-
C-A	1232 (99.92)	-	-	-	1 (0.08)	-	-
M-A	1231 (99.84)	-	-	2 (0.16)	-	-	-
C-M-A	1225 (99.35)	7 (0.57)	-	-	-	-	1 (0.08)

MB:mesiobuccal, DB:distobuccal, P:palatal, C:coronal, M:middle, A:apical.

Table II - Number and percentage of fusion types and locations, positions and levels of canal merging according to fusion types in maxillary second molars

	Types of fusion, n (%)								
	Not	F-Type 1	F-Type 2	F-Type 3	F-Type 4	F-Type 5	F-Type 6	F-Type 7	F-Type 8
Presence of fusion	1091 (77.6)	72 (5.12)	116 (8.25)	4 (0.28)	48 (3.41)	24 (1.71)	32 (2.28)	13 (0.92)	6 (0.43)
Merging situation									
Without merging	1241 (88.27)	20 (1.42)	112 (7.96)	2 (0.14)	17 (1.21)	8 (0.57)	2 (0.14)	-	4 (0.28)
Partial merging	1292 (91.89)	52 (3.69)	4 (0.28)	2 (0.14)	30 (2.13)	6 (0.43)	16 (1.14)	2 (0.14)	2 (0.14)
Multiple merging	1370 (97.44)	-	-	-	1 (0.07)	10 (0.71)	14 (1.0)	11 (0.78)	-
Merging position									
MB-DB	1309 (93.1)	52 (3.69)	-	-	28 (1.99)	-	15 (1.07)	2 (0.14)	-
MB-P	1399 (99.5)	-	4 (0.28)	-	2 (0,14)	-	1 (0.07)	-	-
DB-P	1398 (99.43)	-	-	2 (0.14)	-	6 (0.43)	-	-	-
MB-DB-P	1370 (97.44)	-	-	-	1 (0.07)	10 (0.71)	14 (1.0)	11 (0.78)	-
MP-DP	1404 (99.86)	-	-	-	-	-	-	-	2 (0.14)
Merging level									
Coronal	1398 (99.29)	3 (0.21)	-	-	2 (0.14)	-	2 (0.14)	1 (0.07)	-
Middle	1402 (99.72)	-	1 (0.07)	-	-	-	3 (0.21)	-	-
Apical	1372 (97.58)	12 (0.85)	2 (0.14)	1 (0.07)	9 (0.64)	8 (0.57)	2 (0.14)	-	-
C-M	1401 (99.64)	2 (0.14)	1 (0.07)	-	2 (0.14)	-	-	-	-
C-A	1397 (99.36)	6 (0.43)	-	-	3 (0.21)		-	-	-
M-A	1385 (98.51)	5 (0.36)	-	-	1 (0.07)	4 (0.28)	7 (0.48)	4 (0.28)	-
C-M-A	1347 (95.80)	24 (1.71)	-	1 (0.07)	14 (0.96)	4 (0.28)	16 (1.14)	8 (0.57)	2 (0.14)

MB:mesiobuccal, DB:distobuccal, P:palatal, C:coronal, M:middle, A:apical.

50 years, with a significant difference (p= 0.022). While UC-1 and UC-2 were mostly seen in the coronal region, UC-3 and UC-4 were seen more often in the apical third (Figure 3). UC-1 was observed in 24, 16 and 5 cross-sections of the coronal, middle, and apical thirds, respectively. UC-2 was observed in 16 cases in the coronal region, more frequently in the middle (n = 28)

Table III - Number and percentage of fusion according to gender, age group and tooth position in maxillary first and second molars

	Gender		Age-groups					Tooth position	
	Female	Male	18-30	31-40	41-50	51-60	>60	Left	Right
MFM									
count	51/637*	25/596	20/418	25/424	25/257	4/98	2/36	41/617	35/616
%	8.01	4.19	4.78	5.90	9.73	4.08	5.56	6.65	5.68
MSM									
count	211/756*	104/650	93/482	110/500	78/284	25/104	9/36	158/695	157/711
%	27.91	16	19.29	22	27.46	24.04	25	22.73	21.08
Total	262/1393*	129/1246	113/900	135/924	103/541	29/202	11/72	199/1312	192/1327
%	18.81	10.35	12.56	14.61	19.04	14.36	15.28	15.17	14.47

MFM:maxillary first molar, MSM:maxillary second molar, * indicates statistical differences ($p< 0.05$).

Table IV - Number and percentage of C-shaped canal types in the first and second maxillary molars

	Types of C-shaped canal						
	Not	C-Type A	C-Type B	C-Type C	C-Type D	C-Type E	C-Type F
MFM							
Count	1230	-	-	3	-	-	-
%	99.76	-	-	0.24	-	-	-
MSM							
Count	1353	6	19	2	11	13	2
%	96.23	0.43	1.40	0.14	0.78	0.96	0.14

MFM:maxillary first molar, MSM:maxillary second molar.

Table V -Number and percentage of C-shaped canals according to fusion types, canal merging situation and position in maxillary second molars with fused roots

	Count	%
Type of fusion	53/315	16.83
F-Type 1	6/72	8.33
F-Type 2	3/116	2.64
F-Type 3	0/4	0
F-Type 4	9/48	18.75
F-Type 5	7/24	29.17
F-Type 6	18/32	56.25
F-Type 7	8/13	72.73
F-Type 8	2/6	33.33
Canal merging situation	53/315	16.83
Without merging	1/165	0.61
Partial merging	30/114	26.32
Multiple merging	22/36	61.11
Canal merging position	53/150	35.33
MB-DB	21/97	21.65
MB-P	6/7	85.71
DB-P	3/8	37.5
MB-DB-P	21/36	58.33
MP-DP	2/2	100

MB:mesiobuccal, DB:distobuccal, P:palatal, MP:mesiopalatal, DP:distopalatal.

Table VI - C-shaped canal ratio and percentage of maxillary second molars with fused roots according to gender, age group and tooth position

	Ratio of C-shaped canal	Percentage of C-shaped canal	P value
Gender			
Female	38/211	18.01	> 0.05
Male	15/104	14.42	
Age groups			
18-30	20/93	21.51	> 0.05
31-40	18/110	16.36	
41-50	14/78	17.95	
51-60	1/25	4	
>60	0/9	0	
Tooth positions			
Left	27/158	17.09	> 0.05
Right	26/157	16.56	

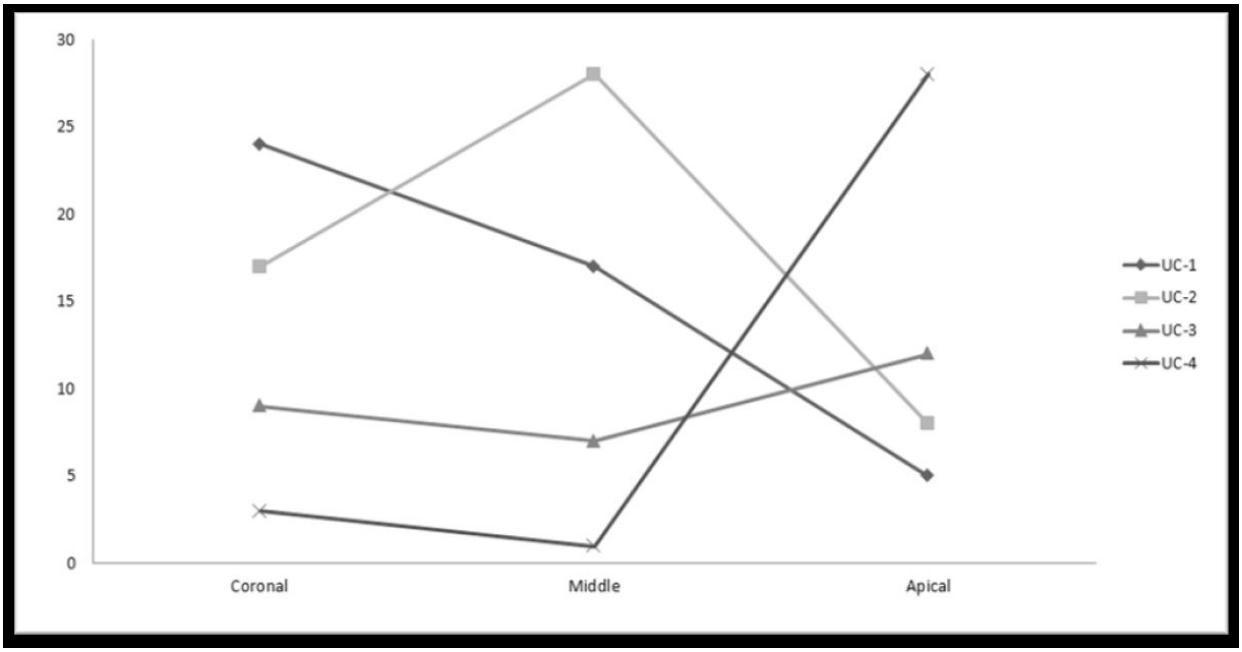

Figure 3 - The number of C-shaped canal configurations in the coronal, middle and apical thirds

and less in the apical (n = 8). UC-3 was similar among the root regions. UC-4 was observed 28 times in the apical third.

DISCUSSION

C-shaped root canal configuration is one of the most commonly described anatomical forms. Some populations have reported a high percentage (up to 42%), especially in second molars [17]. Melton et al. [2] proposed the first classification of C-shaped canals in mandibular molars based on their cross-sectional shape as continuous, semi-colon-shaped or possessing two or three separate canals. Fan et al. [1] modification of this classification is the most commonly used classification today. They added categories with only one round or oval canal and no canal lumen configuration. However, it is not possible to apply these classifications to the upper molars. Root fusion in MMs is different and more complex than in mandibular teeth [18]. The presence of fusion among a large number of roots leads to complex forms of C-shaped canals. In the past few years, researchers have identified C-shaped canal types to overcome the uncertainty in the root and canal morphology of MMs [4,13,14,18]. Jo et al. [4] categorized the C-shaped MMs into three groups based on the number of involved canals as follows: 2-root canals, 3-root canals and unusual

canals. Martins et al. [13] reported five different types with an easy-to-use clinical classification. In the current study, a new modification was proposed by introducing C-type E (not included in Martins et al.'s classification) to accommodate all the different types of configurations encountered in the clinic.

Researchers have proposed three criteria for identifying C-shaped canals in mandibular molars [1-3]: the presence of fusion between the roots; a longitudinal groove that defines the fusion line in the buccal or lingual; and C1, C2 or C3 canal configurations in at least one section. According to these criteria, teeth with three independent canals whose root structure is C-shaped are accepted as part of this group. Martins et al. [13] suggested two criteria for determining C-shaped canals in MMs; the presence of fusion and UC1 and UC2 configurations in three consecutive axial sections (coronal, middle and apical thirds). According to these criteria, clinically-significant cases that are C-shaped in two consecutive sections and separate into independent canals in the apical third, or that start as separate canals but merge from the middle and exhibit a C-shape, are not considered C-shaped. In contrast, a micro-CT study by Ordinola-Zapata et al. [18] reported that the C-shaped configuration rarely extends from the pulp chamber to the apical in MMs. Hence, the current research identified C-shaped canal cases as those that continue throughout a third of the roots.

The incidence of C-shaped canals in the MFMs and MSMs was 0.24% and 3.95%, respectively. These findings are consistent with other studies reporting low prevalence [4,13,14]. Despite the low prevalence in the general population, there was a relatively high rate of 16.83% in fused rooted MSMs. Similarly, Ordinola-Zapata et al. [18] reported a substantial C-shaped canal incidence of 22% in fused rooted MSMs, necessitating caution in the root canal treatment of these teeth. On the contrary, a recent study showed that the C-shaped canal ratio among fused rooted teeth was 5.1% in the MSMs [14]. However, the researchers examined a limited number of images, and only four MSMs had C-shaped canals. Hence, caution is necessary in the interpretation of the results. In studies with small sample sizes, it is difficult to interpret whether the reported values are a true prevalence or incidental, and a larger sample size provides more compelling inferences about the general population.

In our study, MFMs had C-shaped canals in three teeth only; the most commonly observed types were C-type C configuration between the canals of the DB-P roots and F-type 3 (DB-P) fusion. This finding was compatible with some of the previous studies [13,14]. In some studies, C-type B (MB-DB) configuration was most frequently reported [4]. The most common type of configuration in MSMs was C-type B (MB-DB) (n = 19), followed by C-type E (n = 13) and C-type D (n = 11). Additionally, C-type B was most common in the Portuguese and Korean populations [4,13]. Because of the complex nature of C-type D and C-type E, these situations must be approached cautiously or it may result in endodontic treatment failures in these teeth.

Moreover, C-shaped canal systems vary in cross-section from the canal orifice to the apex [18]. In our study, only one tooth exhibited the same canal configuration from the coronal to the apical. The most common forms of UC at the coronal level were UC1 and UC 2; UC3 and UC4 were more dominant towards the apical. We observed that most canals merged and terminated as a single canal at the apical level. The highest incidence of UC-4 in the apical third can increase treatment success rates by ensuring that the apical seal is obtained in the event of missed main canals or isthmus. UC-3 in the apical region may lead to missed canals. Clinically, this is important because the configuration of two or three separate canals in the apical region complicates the chemomechanical preparation, and necrotic pulp tissue and surviving microorganisms are thought to be the primary cause of treatment failure. Among the 53 C-shaped canal MSMs, 13 showed UC1 and UC2 in the apical region, which is hard to debride and disinfect. Therefore, alternative cleaning, irrigation and filling methods should be used in the treatment of these areas.

There are some differences between root canal anatomies of maxillary molar teeth with fused and separated roots, and there is an association between external root morphology and internal root canal anatomy [19]. In fusion types with a higher number of fused roots, the C-shaped canal ratio was more. Teeth with F-types 6 and 7 fusion had over 55% C-shaped

canals. Simpler types of root fusion (2 and 3) showed a very low incidence of C-shaped canal systems. Similarly, previous studies have shown that fusion types with a monoradicular structure had a higher prevalence of C-shaped canals [18]. Furthermore, teeth with multiple canal merging had a high incidence of C-shaped systems (61.11%). An interesting finding is that while the percentage of canal merging between MB-P canals is very low ($n = 7$, 5.04%), these teeth had a high incidence of C-shape ($n = 6$, 85.71%) if the canals did merge. C-shape was present in a quarter of the cases with buccal canal merging.

The incidence of fusion in women was significantly higher in both MFMs and MSMs. However, there was no difference in terms of C-shaped canal incidence. The presence of fusion was more significant than C-shaped canal incidence when comparing genders. C-shaped canal incidence decreased by a statistically significant proportion in individuals over 50 years of age. The main reason for this observation is that the connections between the main canals and the isthmus develop a more regular form or undergo calcification with aging.

Although uncommon, the C-shape anatomy of maxillary molar teeth when clinically encountered is of particular importance. This particular anatomic variant is more frequently seen in complicated fusion cases involving three roots. With a careful radiographic examination before the treatment, it should be ascertained that the roots are not separated and that the monoradicular structure is interpreted and in these teeth the canal orifices may be different, canal merging is expected and the C-shape configuration can be seen.

CONCLUSION

In this study, the incidence of fused rooted MFMs and MSMs was 6.16% and 22.40%, respectively. The prevalence of C-shaped canal anatomy was 0.24% in all MFMs and 3.77% in all MSMs. Among the fused rooted teeth, the prevalence of C-shaped canals in MFMs and MSMs was 3.95% and 16.83%, respectively. The C-shape ratio was substantial, especially in fused rooted MSMs. C-shaped teeth showed different configurations from the coronal to apical. Complex types of fusion were more likely to demonstrate C-shaped canals.

Author Contributions

HA: Protocol development, data collection, data management, data analysis, manuscript writing. ÖÇ: Data management, language editing.

Conflicts of Interest

No conflict of interest

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Regulatory Statement

The study protocol was submitted to the Akdeniz University Medical Ethics Committee to obtain approval before research (process number 70904504/249).

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