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Root Dentine Thickness and Concavity Depth in Mandibular Molars: A Cone Beam Computed Tomography Population Study

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ABSTRACT

Objective: The purposes of the present study were to evaluate dentine thickness and concavity depth below the furcation level of the mesial canals of the mandibular first and second molars, to examine differences between gender, age, and quadrant, and to prove if there is a relationship between root length and dentine thickness.

Methods: Two hundred eleven mandibular first and second molars were included in this study. Samples were divided according to age, gender, quadrant, and root length. Measurements of dentine thickness from the external border of the root canal to the external root surface and concavity depth were recorded 1, 2, and 4 mm below the furcation level. Kruskal–Wallis and Wilcoxon rank sum tests were performed to estimate the influence of different variables, and a multiple regression analysis was performed to evaluate the influence of dentine thickness below the furcation level.

Results: First molars had a deeper concavity depth with significant differences in both 1 mm and 2 mm levels than second molars ($P<0.05$). According to concavity depth, there was no relationship with teeth length ($P>0.05$). The distal concavity was significantly deeper in the 1 and 2 mm levels ($P<0.05$). According to gender, the female group had a reduced dentine thickness in both mesiolingual and mesiobuccal canals in both 1 mm and 2 mm levels ($P<0.05$).

Conclusion: Female patients have a reduced dentine thickness below the furcation level. In order to select the most appropriate instrumentation procedure in every specific case, clinicians must be aware of the dentine reduced thickness measurements to avoid procedural iatrogenic damage.

Keywords: Cone-beam computed tomography, dentine, dental pulp cavity, mandibular, molars

HIGHLIGHTS

- Morphological variability related to geographic populations highlights the importance of anatomic population studies.
- Dentine measurement offers the clinician the necessary information to select the appropriate instrumentation procedure in every specific case to avoid procedural iatrogenic damage.
- The mean root thickness of the mesiobuccal and mesiolingual canals in the mandibular first and second molars beyond the 1 mm level was <1 mm, confirming the elevated risk to insert a post in the mesial mandibular canals.
- Teeth with deeper concavity depth had a reduced dentine thickness in all levels.
- Women had a reduced dentine thickness 1 mm below the furcation level in the mandibular first molars.

INTRODUCTION

A considerable amount of research has been performed to analyse the anatomy of mandibular molars: number of roots, canaltype morphology, pulp chamber landmarks, presence of lateral canals and apical ramifications, and type of isthmuses (1-3). One study showed that the mandibular first molar is the tooth with a greater requirement for endodontic treatment (4). However, data on the thickness of radicular dentine prior to instrumentation are lacking. Moreover, the limited literature available consists of studies of pre- and post-instrumentation comparisons with small sample sizes (5-8).

The distal aspect of the mesial roots of the first and second molars has a concavity below the furcation level described as the danger zone by Abou-Rass and Glick (9). This concavity results in a reduced dentine thickness from the external surface of the mandibular mesial root canals to the external root surface. Therefore, the amount of dentine of the distal aspect is more reduced than it can be presumed with buccolingual radiographs (5,

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10). The mean distance from the wall of the mesial root canals to the distal surface of the root ranges from 0.7 to 1.27 mm (5-7, 10, 11). However, values of this distance range from 0.53 to 2.00 mm. This wide range of values occur because of root anatomy variability (12) and the small number of specimens studied. Thus, it highlights the requirement to know more accurate values/measurements. A reduced dentine thickness is located 2 to 4 mm under the furcation level (8). Kessler et al. (5) reported that the lowest dentine thickness values are located 4 to 6 mm below the canal chamber orifice. Longer roots tend to have a reduced dentine area toward the danger zone (13).

Coronal flaring removes interferences and allows better control of the instruments in one-third of the root canal (14). Additionally, it provides better penetration of the irrigation needle, improving the efficiency of irrigating solutions (14, 15). However, care must be taken to avoid excessive dentin removal with over flaring (9). Root thickness tends to decrease considerably in this area during canal shaping and is particularly prone to excessive weakness and iatrogenic damage including strip perforation (5).

In search of improving root canal shaping, research has led to a constant change in instrument design, cross-section, alloy modifications, sequence, and even rotation mode. This has increased the instruments cyclic and torsional resistance and flexibility, reducing canal transportation and instrument separation (16). However, dentine removal during canal shaping becomes inevitable (14). Knowledge of dentine thickness in this area becomes indispensable prior to determining the most appropriate and safe instrument/s for canal shaping. This can reduce the risk of iatrogenic errors during canal preparation or subsequent complications, such as strip perforations during root canal filling or fractures under functional loads as a result of tooth weakening. According to Bower (10), knowledge of dentine thickness toward the distal concavity will minimize or even eliminate the risk of producing iatrogenic damage at this level.

Available knowledge is limited with regards to the thickness of radicular dentine. In addition, related studies are of small sample sizes and were undertaken on extracted teeth (5-11, 13). This study aimed to evaluate dentine thickness and concavity depth toward the danger zone of the mesial canals of the mandibular first and second molars, to examine differences between gender, age, and quadrant, and to prove if there is a relationship between root length and dentine thickness.

MATERIALS AND METHODS

This was a retrospective study of cone beam computed tomography (CBCT) images. The Institutional Ethics in Research Committee (END.ECM-2016-03) reviewed and approved the study.

Patient population selection

Patients who had undergone CBCT scanning for endodontic or implant treatment planning at the University Clinic were included from a consecutive referral list from the Romexis software (Planmeca, Helsinki, Finland) between July 2014 and January 2017.

Inclusion criteria

Inclusion criteria were Spanish patients >18 years, those with small volume CBCT scans that were performed (ProMax 3D; Planmeca) with constant exposure parameters of 90 kV, 12.0 mA, and 12.23 s, those with scans with a 5×5 cm field of view with a voxel size of 75 μm, presence of fully matured and erupted mandibular permanent first and second molars with two mesial root canals, and those with mandibular first and second molars with no previous root canal treatment.

A single observer selected all the cases. Clinical charts were also revised for patient nationality, age, and sex because inclusion of some of these variables was not always introduced correctly in the Romexis software. A total of 127 scans fulfilled the inclusion criteria and were included for evaluation from the 487 initial scans.

The sample size was based on a convenient sample of the available patient records. There were no statistical methods used to predetermine the sample size.

Imaging procedure details

A single observer performed all the measurements. Supervision was performed in the initial cases by one of the researchers. CBCT section images were evaluated at 1, 2, and 4 mm from the furcation level (Fig. 1). The minimum dentine thickness from the external surface of the mesiobuccal (MB) and mesiolingual (ML) canals toward the danger zone

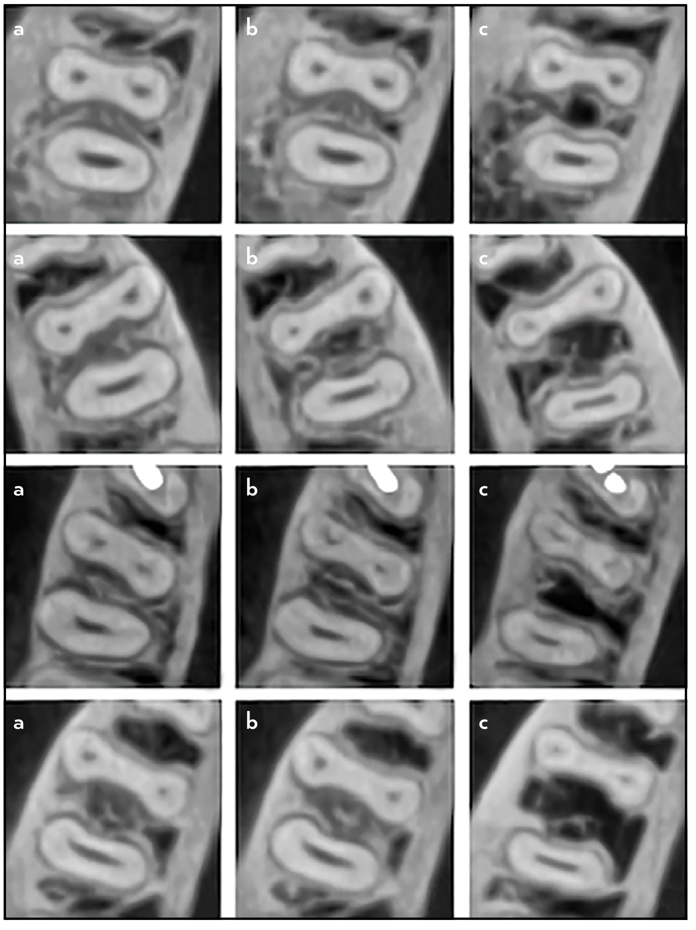

Figure 1. Representative CBCT image sections under the furcation in level 1 mm (a), 2 mm (b), and 4 mm (c)

TABLE 1. Dentine thickness and concavity depth at 1, 2 and 4 mm below the furcation level for the mesiodistal (MD) and buccolingual (BL) canals. Mean and standard deviation in mm. Total, gender, age and quadrant results

		Mandibular first molar (n=114)						Mandibular second molar (n=97)						Root length (1st M)	Root length (2nd M)
		1 mm (MB)	1 mm (ML)	2 mm (MB)	2 mm (ML)	4 mm (MB)	4 mm (ML)	1 mm (MB)	1 mm (ML)	2 mm (MB)	2 mm (ML)	4 mm (MB)	4 mm (ML)		
Total	D. thickness	$1.01^{a}\pm0.21$	$1.03^{a}\pm0.18$	$0.95^{ab}\pm0.19$	$0.98^{ab}\pm0.19$	$0.92^{b}\pm0.20$	$0.94^{b}\pm0.19$	$1.08^{a}\pm0.26$	$1.08^{a}\pm0.24$	$1.00^{ab}\pm0.24$	$1.01^{ab}\pm0.22$	$0.95^{b}\pm0.22$	$0.95^{b}\pm0.20$	$10.49^{a}\pm1.14$	$9.99^{b}\pm1.20$
	C. depth	$0.68^{a}\pm0.23$		$0.68^{a}\pm0.22$		$0.61^{b}\pm0.23$		$0.47^{c}\pm0.29$		$0.60^{bd}\pm0.28$		$0.56^{bd}\pm0.28$			
Gender															
Male (n=60)	D. thickness	$1.07^{a}\pm0.21$	$1.08^{a}\pm0.18$	$0.98^{a}\pm0.18$	$1.02^{a}\pm0.24$	$0.96^{a}\pm0.20$	$0.98^{a}\pm0.23$	$1.06^{a}\pm0.25$	$1.08^{a}\pm0.21$	$0.99^{a}\pm0.18$	$0.99^{a}\pm0.19$	$0.94^{a}\pm0.20$	$0.94^{a}\pm0.19$	$10.55^{a}\pm1.14$	$9.98^{b}\pm1.23$
Female (n=67)	C. depth	0.69±0.29		0.70±0.25		0.64±0.25		0.51±0.30		0.61±0.27		0.60±0.26			
	D. thickness	$0.96^{b}\pm0.20$	$0.98^{b}\pm0.17$	$0.92^{b}\pm0.20$	$0.94^{b}\pm0.16$	$0.89^{a}\pm0.20$	$0.92^{a}\pm0.17$	$1.08^{a}\pm0.27$	$1.07^{a}\pm0.26$	$1.00^{a}\pm0.27$	$1.02^{a}\pm0.24$	$0.96^{a}\pm0.24$	$0.96^{a}\pm0.22$	$10.45^{a}\pm1.17$	$9.94^{b}\pm1.15$
	C. depth	0.67±0.19		0.67±0.20		0.59±0.22		0.41±0.26		0.57±0.29		0.54±0.30			
Age															
18-30 (n=47)	D. thickness	0.99±0.24	1.06±0.22	0.94±0.22	0.97±0.24	0.92±0.21	0.94±0.21	1.07±0.28	1.11±0.26	0.99±0.24	1.00±0.24	0.96±0.23	0.97±0.23	$10.65^{a}\pm1.37$	$10.03^{b}\pm1.33$
	C. depth	0.67±0.21		0.65±0.22		0.58±0.22		0.45±0.26		0.59±0.29		0.50±0.29			
31-50 (n=43)	D. thickness	1.01±0.19	1.00±0.16	0.93±0.17	0.95±0.14	0.90±0.18	0.95±0.17	1.08±0.22	1.05±0.23	0.96±0.21	1.01±0.20	0.96±0.21	0.96±0.20	$10.40^{a}\pm1.07$	$10.00^{b}\pm1.05$
	C. depth	0.72±0.26		0.74±0.22		0.69±0.25		0.46±0.30		0.59±0.28		0.61±0.31			
>50 (n=34)	D. thickness	1.05±0.20	1.03±0.17	0.99±0.19	1.03±0.18	0.96±0.21	0.96±0.22	1.08±0.28	1.08±0.23	1.05±0.26	1.03±0.22	1.05±0.26	0.91±0.18	$10.41^{a}\pm0.90$	$9.82^{b}\pm1.07$
	C. depth	0.65±0.23		0.65±0.19		0.57±0.20		0.48±0.29		0.58±0.27		0.61±0.23			
Quadran															
46-47 (n=108)	D. thickness	0.98±0.20	1.02±0.16	0.93±0.18	0.95±0.18	0.90±0.17	0.91±0.18	1.04±0.21	1.09±0.22	0.97±0.20	1.00±0.21	0.92±0.20	0.93±0.21	$10.48^{a}\pm1.18$	$9.74^{b}\pm1.12$
	C. depth	0.68±0.21		0.69±0.23		0.62±0.22		0.42±0.27		0.56±0.29		0.52±0.29			
36-37 (n=103)	D. thickness	1.04±0.21	1.03±0.21	0.96±0.20	0.99±0.19	0.94±0.21	0.96±0.19	1.09±0.29	1.06±0.26	1.01±0.26	1.01±0.23	0.97±0.24	0.97±0.20	$10.52^{a}\pm1.13$	$10.19^{b}\pm1.20$
	C. depth	0.68±0.26		0.68±0.21		0.62±0.23		0.51±0.29		0.64±0.29		0.61±0.30			

*Means that share a same superscript letter within each section are not statistically significantly different at each level (P>.05). Means with different superscript letter within each section are statistically significantly different at each level (P<.05).

TABLE 2. Regression analysis of the relationship of the different variables with the dentine thickness of the 1mm section below the furcation level of mandibular first and second molars

Variable	Estimated	Standard error	Inferior limit	Superior limit CI 95%	P-value CI 95%
Age	0.0025	0.2068	0.3551	1.1753	0.0590
Length	0.0312	0.0169	-0.0023	0.0647	0.0678
Quadrant	0.0069	0.0389	-0.0702	0.0841	0.8592
Sex	-0.1118	0.0012	0.0001	0.0049	0.0044*
Depth	-0.0196	0.0809	-0.1801	0.1408	0.8089
Variable	Estimated	Standard error	Inferior limit CI 95%	Superior limit CI 95%	P-value
Age	0.0006	0.0017	0.0012	0.0041	0.7211
Length	0.0451	0.0234	-0.0013	0.0916	0.0570
Quadrant	0.0342	0.0552	-0.0753	0.1439	0.5361
Sex	0.0152	0.0540	-0.0921	0.1226	0.7784
Depth	-0.1591	0.0981	-0.3541	0.0357	0.1083

*Means statistically significant (P<.05)

was measured according to Lim and Stock (7). In addition, concavity depth in the distal surface of the mesial roots was recorded in the deepest point (13). Root length was also measured from the furcation level to the apex. The Planmeca Romexis dental imaging software was used for dentine measurements.

Statistical analysis

Values of central tendency and dispersion were calculated using the Statgraphics Centurion XV software (StatPoint Technologies, Inc., Warrenton, VA, USA). Owing to the non-normal distribution and lack of homogeneity of the variance, data were analyzed statistically by Kruskal–Wallis and Wilcoxon rank sum tests to estimate the influence of age, sex, and quadrant.

In addition, a multiple logistic regression was used to evaluate the correlation of different variables to dentine thickness of the 1 mm section below the furcation level of the mandibular first and second molars. A P-value <0.05 was considered as significant.

RESULTS

A total of of 127 (67 female and 60 male) patients composed the study population. The mean age of the patients was 39.06 (18–72) years. Hence, 211 teeth with 422 root canals were included for further analysis.

Table 1 shows the dentine thickness and concavity depth measurements in the three levels evaluated below the furcation level (1, 2, and 4 mm). The mandibular first molars resulted to have similar dentine thickness mean values compared with the second mandibular molars at the three levels studied (P<0.05). However, the first molars had a deeper concavity depth with significant differences in the 1 mm level (P<0.05) and in the 2 mm level (P<0.05) compared with the second molars.

Teeth with deeper concavity depth had a reduced dentine thickness in all levels (P<0.05). Multiple regression analysis showed that only sex had an influence on dentine thickness (P<0.05). Women had a reduced dentine thickness 1 mm below the furcation level in the mandibular first molars (Table 2).

The first mandibular molars had longer roots than the second mandibular molars (P<0.05). There was no relationship between root length and dentine thickness (P>0.05). However, when categorizing root length into three groups (<12, 10–12, and <10) for comparison with the results by Dwivedi et al. (13) and Sauáia et al. (14), a relationship was found between root length and dentine thickness. This was only significant at the 4 mm level below the furcation of the MB in the first molars (P<0.05). Longer teeth had a reduced dentine thickness only at this level. According to concavity depth, no relationship was found (Table 3).

Mandibular first molars

There were no significant differences between dentine thickness in the MB and ML canals (P>0.05). However, there was a significantly reduced dentine thickness in the 4 mm level compared with the 1 mm level in both MB (P<0.05) and ML (P<0.05) canals. The distal concavity was significantly deeper in the 1 and 2 mm levels compared with the 4 mm level below the furcation (P<0.05).

According to gender, the female group had a reduced dentine thickness compared with the male group in both ML and MB canals in the 1 mm (P<0.05) and the 2 mm (<0.05) levels below the furcation. There were no differences according to age or between the left and the right mandibular quadrants (P>0.05). No differences were found according to root length and dentine thickness or concavity depth (P>0.05).

Mandibular second molars

There was a significantly reduced dentine thickness in the 4 mm level compared with the 1 mm level in both MB (P<0.05) and ML (P<0.05) canals. According to concavity depth, the distal concavity was found to be deeper at the 1 mm level compared with the 2 mm and 4 mm levels (P<0.05). There were no differences according to sex, age, or quadrant. No differences were found according to root length and dentine thickness (P>0.05).

TABLE 3. Relationship with root length and dentine thickness and concavity depth at 1, 2 and 4 mm below the furcation level for the mesiodistal (MD) and buccolingual (BL) canals. Mean and standard deviation in mm

		Mandibular first molar						Mandibular second molar						Root length (1st MM)	Root length (2nd MM)
		1 mm (MB)	1 mm (ML)	2 mm (MB)	2 mm (ML)	4 mm (MB)	4 mm (ML)	1 mm (MB)	1 mm (ML)	2 mm (MB)	2 mm (ML)	4 mm (MB)	4 mm (ML)		
Root Length															
>12 mm	D. thickness	1.08±0.23	1.07±0.19	1.00±0.20	0.99±0.21	1.03±0.22	0.99±0.20	1.20±0.36	1.24±0.29	1.13±0.33	1.15±0.28	1.09±0.28	1.07±0.25	11.97±0.60	11.44±0.37
	C. depth	0.73±0.27		0.74±0.23		0.64±0.24		0.44±0.32		0.62±0.32		0.60±0.30			
10-12 mm	D. thickness	1.00±0.20	1.02±0.22	0.93±0.18	0.97±0.20	0.92±0.19	0.96±0.21	0.99±0.19	0.94±0.18	0.93±0.19	0.90±0.20	0.88±0.16	0.87±0.17	10.51±0.29	10.48±0.29
	C. depth	0.65±0.21		0.67±0.20		0.64±0.22		0.60±0.20		0.69±0.24		0.63±0.27			
<10 mm	D. thickness	0.99±0.19	1.01±0.15	0.93±0.21	0.91±0.19	0.86±0.18	0.91±0.19	1.06±0.21	1.08±0.20	0.96±0.17	1.00±0.17	0.92±0.20	0.93±0.18	9.38±0.47	8.95±0.62
	C. depth	0.66±0.22		0.64±0.21		0.56±0.21		0.40±0.28		0.52±0.26		0.50±0.28			

*Means that share a same superscript letter within each column are not statistically significantly different at each level (P<.05).

DISCUSSION

Crown-down techniques have been recommended for shaping root canals. Preflaring before reaching the working length permits apical enlargement with a reduced risk of transportation and procedural errors (15, 16). In addition, it results in a better access of irrigating solutions to the apical one-third, thus improving its efficiency (9, 17). However, an excessive coronal shaping may lead to iatrogenic complications, such as perforations and stripping, particularly in the inner surface of the curve (5, 9). Iatrogenic communications in the cervical third can lead to inflammatory response and breakdown of supporting structures (18). The excessive structure loss, even without communication with the periradicular tissues, leads to a reduced resistance to root fracture under functional loads (16). A minimum dentine thickness of 0.3 mm is recommended to withstand forces during root canal filling (7). However, dentine thickness is directly related to resisting lateral forces and functional loads, reducing the risk of root fracture (16, 19), and Caputo and Standlee (20) recommended a minimum of 1 mm.

The distal concavity in the mesial roots below the furcation makes this tooth prone to suffer from stripping or perforations. Reduced dentine thickness at this level cannot be appreciated with periapical radiographs, and root canal shaping in this area sometimes becomes a challenge. Thus, a wide population analysis is essential to have a more accurate mean and range values, providing more valuable information to know what instrumentation procedure or instruments should be used to reduce the risk of iatrogenic damage. However, studies have used a small number of extracted teeth and measured by sectioning procedures. CBCT is considered as a useful approach to reach a pre-intervention diagnosis and provide high-resolution imaging (21). The ALARA criteria do not allow to pre-scan every patient who requires root canal treatment. Thus, the population sample included with CBCT images of small field of view was difficult to obtain, and the CBCT images included were obtained from a time span from 2014 to 2017.

Dentin thickness has only been measured in sections of extracted teeth with a small number of samples in few in vitro studies. Isom et al. (8) studied 26 mandibular extracted molars and found that dentine thickness at the furcation level ranges between 0.74–2 mm 1 mm below the furcation level, 0.69–2 mm 2 mm under the furcation level, and 0.53–1.91 mm 4 mm under the furcation level. Results in our demographic study showed that dentine was thinner in the mandibular first molars, ranging between 0.47 and 1.86 mm with means ranging between 0.92 and 1.01 mm. This highlights the importance of establishing an adequate instrumentation procedure when shaping the mesial mandibular canals to avoid iatrogenic damage, especially in the mandibular first molars. Despite measurements of dentine thickness do not differ much between MB and ML canals, previously described differences in canal curvature make the MB canals more prone to suffer from iatrogenic damage during mechanical instrumentation (22). As there is a 28%–42% of confluence in the apical third (23), the ML canal has been recommended to be prepared first (6).

Two in vitro studies (13, 14) have studied the correlation of root length and dentine thickness 2 mm below the furcation level of extracted teeth. They concluded that the longer teeth have a thinner dentine thickness toward the danger zone. Crown enamel/dentine wear is a common feature in most patients. Moreover, several patients who undergo root canal treatment have a full-coverage restoration, or an occlusal adjustment has been performed. Hence, occlusal reference points are not a feasible method to determine teeth length. Thus, we measured root length instead, what can be more useful in a clinical situation. However, we maintained a linear measurement of length without taking into account the root canal curvature to compare our results with those studies (13, 14). In contrast with their results, in the present study, there was no correlation with longer teeth and a reduced dentine thickness toward the danger zone or a deeper concavity (P>0.05). Differences found can be attributed to differences in the methodology procedure, population variability, or sample size. In our study, only Spanish Caucasian individuals were included. However, the source population was not mentioned in other studies (13, 14). In addition, age, gender, and quadrant were unknown. Future research is needed to determine whether different populations have more or less risk of stripping during canal preparation. In addition, more studies are needed to determine the dentine thickness in maxillary molars to evaluate the risk of stripping and possible iatrogenic damage during root canal treatment and especially in the MB roots. However, when root length was considered as a category, there was a correlation only at the 4 mm level below the furcation (P>0.05).

According to our study, female patients have a reduced dentine thickness below the furcation level with significant differences in the 1 mm and the 2 mm levels in both ML and MB canals (P<0.05). Dentine deposition and canal calcification related to aging do not appear to significantly alter dentin thickness below the furcation level, and no difference was found in the present study according to age (P>0.05).

According to the inclusion criteria, for an improved resolution imaging, only small field of view CBCTs were selected. Thus, no complete mandibular arch was available for inclusion. Differences between the left and the right molars have to be considered as a demographic sample and not as individually related. In addition, resolution of CBCT is lower than that of microcomputed tomography. However, for obvious reasons, CBCT scans were used in the present population study. Despite the lower resolution, as evaluating only the coronal level of the root and root canal and not the apical one-third, the resolution seems to be enough to measure dentine thickness (24, 25).

The mean root thickness of the MB and ML canals in the mandibular first and second molars beyond the 1 mm level was <1 mm. In accordance with Akhlaghi et al. (26), these results confirm the elevated risk to insert a post in the mesial mandibular canals. A minimum tooth structure of 1 mm surrounding a post to prevent vertical root fracture has been recommended (20, 27).

Several instruments have been proposed for the preparation of the cervical third of the root canals. Recently, Flores et al. (28) compared the effects of different access instruments in dentine removal. They found a dentine removal of 0.18–0.34 mm after using Gates-Glidden, Largo, LA-Axxess, and CPdrill during endodontic access. Furthermore, to this amount, dentine removal produced during canal shaping has to be added.

As we increase apical diameter, coronal dentine removal also increases with significant differences when performing apical enlargement up to #35–40 compared with #25–30 instruments (29). In addition, dentine removal varies depending on the instrument or sequence used. Zhao et al. (30) compared preparations up to 30.06 using Twisted files, HyFlex, and K3 instruments, resulting in a dentine removal of 0.30–0.56 mm. Capar et al. (31) used six different instruments with a #25 tip, resulting in 0.15–0.22 mm of dentine removal.

CONCLUSION

In conclusion, only sex was related to dentine thickness below the furcation level. Female patients had a reduced dentine thickness at this level. Knowledge of the root dentine thickness below the furcation level is essential to prevent iatrogenic damage. Clinicians must be acquainted with these measurements in order to select the most appropriate instrumentation procedure in every specific case to achieve endodontic procedure principles, avoiding procedural accidents as strip perforations.

Disclosures

Conflict of interest: The authors deny any conflicts of interest.

Ethics Committee Approval: The Institutional Ethics in Research Committee (END.ECM-2016-03) reviewed and approved the study.

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