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ORIGINAL ARTICLE

Comparison of Dentinal Wall Thickness in the Furcation Area (Danger Zone) in the First and Second Mesiobuccal Canals in the Maxillary First and Second Molars Using Cone-Beam Computed Tomography

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ABSTRACT

Objective: Differences in the morphology of the root canal system might result in favorable or adverse treatment outcomes. The present study compared the thickness of the dentinal wall in the danger zone (furcation area) of the first and second mesiobuccal canals in the maxillary first and second molars using cone beam computed tomography.

Methods: In this cross-sectional study, 50 CBCT images of maxillary first and second molars were evaluated from one of the specialized radiology centers in Kerman, Iran. The images were prepared by a Planmeca Promax 3D Max machine (Planmeca, Helsinki, Finland), with a field of view (FOV) of 8×8 cm and a resolution of 0.1 mm and analyzed with Romexis Viewer software version 3.1.1 (Planmeca, Helsinki, Finland). In the 0.1-mm-thick axial cross-sections with a distance of 1 mm, the distances from the center of the MB1 and MB2 root canals to the furcation area were measured in three areas: A) furcation area, B) 2 mm below the furcation area, and C) 4 mm below the furcation area (at a magnification of ×10). The data were then analyzed with paired t-test.

Results: The thickness of the dentinal wall in the MB2 root canal was significantly less than that in the MB1 root canal in all the specimens ($P<0.05$). In both maxillary first and second molars, the thicknesses of the MB1 and MB2 root canals were significantly different in the furcation area and 4 mm below the furcation area ($P=0.001$). There was no significant difference between the maxillary first and second molars 2 mm below the furcation area; however, the difference was marginal ($P=0.07$).

Conclusion: Considering the low thickness of the dentinal wall in the MB2 root canal compared with the MB1 root canal in the maxillary first and second molars, the anti-curvature techniques away from the furcation should be used to prepare this root canal to reduce the risk of strip perforation. On the other hand, it might indicate that highly tapered instruments and other aggressive instruments, such as Gates-Glidden drills, should be used with caution in these root canals.

Keywords: Cone-beam computed tomography, danger zone, maxillary molars, thickness of dentin

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HIGHLIGHTS

- This CBCT study evaluated and compared the thickness of the dentinal wall in the danger zone of the first and second mesiobuccal root canals in the maxillary first and second molars.
- Measurement of dentine thickness provides the clinician with the necessary information to select the appropriate instrumentation procedure in every specific case to avoid procedural iatrogenic damage.
- The thickness of the dentinal wall around the MB2 root canal was significantly less than that around the MB1 root canal in both maxillary first and second molars.
- Considering the lower thickness of the denintal wal laround the MB2 root canal compared with the MB1 root canal in the maxillary first and second molars, the anti-curvature technique should be used to prepare this root canal to reduce the risk of strip perforation.

INTRODUCTION

The root canal therapy of maxillary molars encompasses a high percentage of endodontic treatments (1). The tooth anatomy is complicated, and the endodontic treatment poses a significant challenge for clinicians (2). Some specific factors, such as ethnicity region, gender, and age affect the presence of the second mesiobuccal root canal (MB2) in the molar mesiobuccal roots (3). Cleghorn's et al. (4) reported that MB2 root canal is observed in more than 90% of cases. Persistent endodontic disease in maxillary molars is often attributed to the presence of an untreated MB2 root canal (5).

Due to the deposition of secondary dentin, the second mesiobuccal root canal orifice is smaller than that of the first mesiobuccal root canal in the majority of cases (6). In addition to complete recognition of the mesiobuccal root canal anatomy in maxillary molars, clinicians should pay special attention to this root canal during the preparation of the second mesiobuccal root canal since some studies have documented that this root canal is thinner than the first mesiobuccal root canal in maxillary molars (7). If the clinician disregards the minimum residual thickness of the dentin wall during the treatment process, the clinician will face unexpected conditions, such as strip perforation.

Strip perforation refers to an oblong, vertical perforation that occurs especially in curved root canals, caused by excessive instrumentation of the inner wall (8). This type of root injury usually occurs 1 to 3 mm below the furcation area (from the coronal one-third to the middle one-third) in the danger zone. This type of perforation is more common in the mesial root canals of maxillary and mandibular molars and can be prevented through gaining proper knowledge about the anatomy of the canals and dentinal wall thickness in the furcation area and changing the canal preparation techniques (7).

Researchers have used several methods to gain knowledge about the anatomy of the mesiobuccal root canal(s) in the maxillary molars. These techniques are classified into two broad categories: laboratory techniques and clinical techniques. Laboratory techniques include sectioning, clearing and pulp chamber observation under an electron microscope. Clinical techniques consist of observation during endodontic treatment, radiography, and patient records (4).

Given the benefits of Cone beam computed tomography (CBCT) in endodontic treatments, this technique has been used in detection of apical periodontitis, complex root canal morphology (additional roots, canals and root curvatures), assessment of root perforations, vertical root fractures and root resorption. Furthermore, this technique has been reported to be associated with a higher rate of diagnostic accuracy compared with periapical radiography (9).

Although several studies have examined the morphological features of the mesiobuccal root canal(s) in maxillary second molars (4), there are several limitations about measuring the thickness of the dentinal wall in the furcation area.

The present study compared the thickness of the dentinal wall in the furcation area in the first and second mesiobuccal root canals of maxillary molars using the CBCT technique.

MATERIALS AND METHODS

In this in vitro study, 100 CBCT images of the maxillary first (n=50) and second (n=50) molar teeth were randomly selected from the image archives of radiology centers in Kerman, Iran, with no age limitations for sample selection.

Since the data were collected from the image archives of radiology centers and the patients' demographic data were kept confidential, no consent of patients was required. The Ethics Committee reference number was IR.KMU.REC.1394.509.

Inclusion criteria

1. CBCT images of the maxillary first and second molars on one side (left or right)
2. Teeth with three separate roots: mesiobuccal, distobuccal, and palatal
3. Teeth with no root fractures
4. Teeth with no external and internal resorption
5. Teeth with no root canal treatment
6. Teeth with no calcification
7. Teeth with a second mesiobuccal root canal

For the primary evaluation, the panoramic views of the first and second maxillary molars were prepared from the CBCT images (Fig. 1a). From the images with an FOV of 8×8 cm and a resolution of 0.1 mm, the axial sections were prepared with a thickness of 0.1 mm and a distance of 1 mm between the sections (Planmeca Promax 3D Max), followed by analysis with Romexis 3.1.1 software. The specimens were examined by a trained dental student; then, some of the specimens were randomly re-evaluated by a radiologist to eliminate any measurement errors.

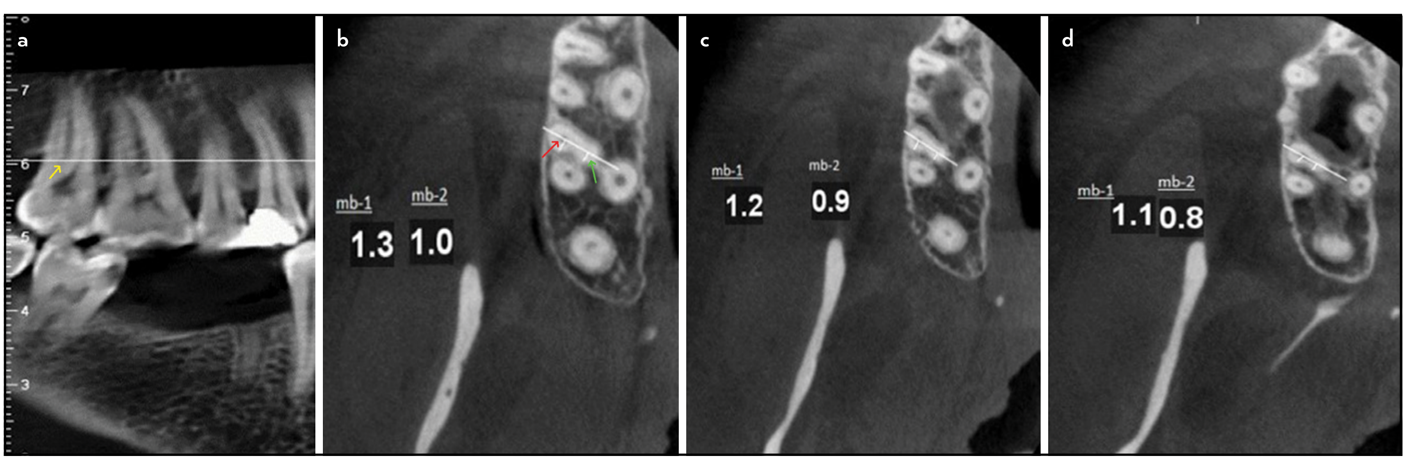

Figure 1. (a) The approximate furcation area of tooth 17 on the panoramic view (yellow arrow). (b) The distance from the center of the MB1 (red arrow) and MB2 (green arrow) root canals to the furcation area of tooth 17 (axial view). (c) The distance from the center of MB1 and MB2 root canals to 2 mm below the furcation area of tooth 17 (axial view). (d) The distance from the MB1 and MB2 root canals to 4 mm below the furcation area of tooth 17 (axial view)

After specifying the desired furcation section in the panoramic image and the axial view of the specimens, the researchers measured the distance between the center of the root canal and the furcation area in MB1 and MB2 root canals in three sections: A) furcation area, B) 2 mm below the furcation area, and C) 4 mm below the furcation area.

These distances were measured by drawing a line from the center of the root canal orifices to the furcation section with the least distance from each root canal center (Fig. 1b). For the distances from 2 and 4 mm below the furcation section, the boundary of this section was first determined on the panoramic image and measured in an axial view as described (Figs. 1c and 1d).

Six measurements were made in each tooth. The thicknesses of the MB1 and MB2 root canal walls were measured in the three sections mentioned above.

Statistical analysis

The means and standard deviations of the thickness of the MB1 and MB2 root canal walls in the maxillary first and second molars were calculated for descriptive statistics. Normality of the distributions was checked by Kolmogorov–Smirnov test. Thereafter, the results were analyzed by paired t-test. The level of significance was set at $P<0.05$.

RESULTS

In the maxillary first and second molars, the thickness of the MB2 root canal wall in the furcation area was significantly less than that of the MB1 root canal wall ($P<0.05$).

In the maxillary first and second molars, the thicknesses of the MB1 and MB2 root canal walls were significantly different in the furcation area and 4 mm below the furcation area ($P=0.001$). There was no significant difference between the maxillary first and second molars 2 mm below the furcation area; however, the difference was marginal ($P=0.07$). The comparison between the thicknesses of the sections measured in the maxillary first and second molars is shown in Table 1, indicating that the wall thicknesses of the MB1 and MB2 root canals in the maxillary first and second molars were similar in all the sections. As an exception, the thickness of the MB1 root canal wall of the second molar 2 mm below the furcation area was significantly less than that of the MB1 root canal wall of the first molar ($P=0.006$).

Table 2 presents the maximum, minimum, mean, and standard deviation values for each of these six sections in mm.

DISCUSSION

This study compared the thickness of the dentinal wall in the maxillary molar teeth in the furcation area at three sections for the evaluation of the first and second mesiobuccal root canals.

In addition to the knowledge about the most appropriate procedure for successful endodontic treatment, thorough knowledge of the tooth anatomy is a key factor affecting the treatment outcome (4, 10). The root canal system in the mesiobuccal roots of maxillary molars is complicated, and given the high prevalence of MB2 root canals in these teeth (4, 6) and the limited information about dentin thickness in the danger zone of the mesiobuccal root (6), the mesiobuccal root

TABLE 1. Distance from centre of root canal to furcation area

Sections	n	Min	Max	SD	Mean
MB1 root canal dentin thickness from the furcation area in teeth	100	0.80	1.50	0.15	1.01
MB1 root canal dentin thickness at 2 mm below the furcation area in teeth	100	0.60	1.50	0.16	1.02
MB1 root canal dentin thickness at 4 mm below the furcation area in teeth	100	0.60	1.40	0.17	0.90
MB2 root canal dentin thickness from the furcation area in teeth	100	0.40	1.50	0.17	0.90
MB2 root canal dentin thickness at 2 mm below the furcation area in teeth	100	0.30	0.70	0.64	0.91
MB2 root canal dentin thickness at 4 mm below the furcation area in teeth	100	0.30	1.40	0.20	0.81

SD: Standard devision

TABLE 2. A comparison of sections in the maxillary first and second molars

	Tooth	n	Mean	SD	P
MB1 root canal dentin thickness from the furcation area in teeth	First molar	50	1.12	0.21	0.51
	Second molar	50	1.09	0.19	
MB1 root canal dentin thickness 2 mm below the furcation area in teeth	First molar	50	1.04	0.19	>0.01
	Second molar	50	1.01	0.13	
MB1 root canal dentin thickness 4 mm below the furcation area in teeth	First molar	50	0.99	0.16	0.09
	Second molar	50	0.94	0.18	
MB2 root canal dentin thickness from the furcation area in teeth	First molar	50	0.92	0.16	0.72
	Second molar	50	0.89	0.18	
MB2 root canal dentin thickness 2 mm below the furcation area in teeth	First molar	50	0.86	0.19	0.24
	Second molar	50	0.96	0.88	
MB2 root canal dentin thickness 4 mm below the furcation area in teeth	First molar	50	0.83	0.21	0.79
	Second molar	50	0.79	0.19	

SD: Standard devision

canals of the maxillary first and second molars were evaluated in the present study.

This study showed that the wall thickness of MB2 root canal was significantly less in the maxillary first and second molars compared to the MB1 root canal, with no significant difference in the thickness of MB1 and MB2 root canals between the maxillary first and second molars.

Currently, the CBCT technique has become very popular in research studies because it makes 3D visualization of anatomical structures possible, minimizing the superimposition of surrounding structures (11). The CBCT, as a non-invasive imaging technique with high accuracy, is beneficial for a variety of cases, such as detection of additional canals (9), measurement of dentin thickness in danger zones (12), and perforation detection (13); hence, it can make endodontic treatment more successful. The CBCT technique was used in this study. Although several studies have examined the root canal morphology using this technique (14, 15), no study has investigated the danger zone thickness in maxillary molars using this method.

In this study, the distances from the center of the MB1 and MB2 root canals to the furcation area were measured in three areas: the furcation area, 2 mm below the furcation area, and 4 mm below the furcation area, which were selected based on similar studies (7). Degerness et al. (6) reported that the danger zone in the maxillary molars lies at the crown–root interface. Shahravan et al. (7) claimed that as the distance from the CEJ increases, the dentin thickness of the maxillary first molars decreases in both the MB1 and MB2 root canals and the average wall thickness of the furcation area 4 mm below the CEJ in the MB2 root canals is only 1.36 mm, and the strip perforation is likely.

Stainless steel manual files and nickel–titanium rotary files are used for root canal widening. Excessive flaring by these instruments, especially in the curved roots and in areas with low dentin thickness, might result in thinning or perforation of the root canal wall on the concave root surface (16). The use of NiTi rotary tools in curved canals and areas with low dentin thickness is more preferable because they preserve the natural shape of the root canal and reduce the risk of canal transportation and perforation, compared to stainless steel manual instruments (7, 17, 18). Lim et al. (19) demonstrated that the minimum residual dentin thickness to withstand the forces imposed during root canal filing and tooth function should not be <0.3 mm. Morfis et al. (20) reported that the minimum residual dentin thickness was reversely correlated with the odds of tooth fracture. The results of their study also revealed that excessive dentin removal increased the risk of vertical root fracture.

In 1980, Abou-Rass et al. (21) proposed the 'anticurvature filing' technique for the preparation of the curved canals and areas with low dentin thickness. This method is a controlled preparation technique directed toward the thicker root area or the safe zone and away from the thinner root area or danger zone where the root canal wall is likely to be perforated or stripped. Two studies by Abou-Rass et al. (21) and Oliveria et al. (16) also suggested that the risk of perforation decreases in thinner root areas or danger zone due to the use of the anticurvature instrumentation technique.

In conclusion, the clinicians should have the necessary knowledge of the root anatomy and areas with low dentin thickness in order to prevent errors, such as thinning or perforation of the root canal walls while using an appropriate instrument for preparing the root canal.

Various studies have used different techniques, such as histological sections, serial sections, clearing, scanning electron microscopy, stereomicroscopy, radiography, CBCT, and micro-CT, to evaluate the risk of perforation in the root canal system (12). Among the methods that can be applied in vivo, CBCT is a suitable method for detecting the complicated root canal system and evaluating dentin wall thickness because it allows for three-dimensional evaluation (22). *In vitro* studies have used both micro-CT and stereomicroscopy as the gold standard to evaluate the root canal system (12).

Mohammadzadeh et al. (10) estimated the thickness of the mesiobuccal root of maxillary first molars in 40 extracted teeth using the radiography technique and found that the least thickness in the teeth with one mesiobuccal canal was in the distal and mesial canal areas. They also reported that the least thickness in the teeth with two mesiobuccal root canals was in the distobuccal and distopalatal areas. It was also observed that dentin thickness in the mesiobuccal root was the greatest in the buccal and palatal areas. On the other hand, Raiden et al. (23) claimed that radiography is not an appropriate method for evaluating root canal wall thickness, and clinicians should keep in mind that the real root canal wall thickness is less than that observed on radiographs. Ordinola-Zapata et al. (24) used the micro-CT technique to evaluate dentin thickness in the danger zone of the mesiobuccal roots of the maxillary first molars. They reported that the average dentin thickness 2–3 mm apical to the furcation area adjacent to the MB2 root canal was significantly lower on the mesial and distal sides compared to the MB1 root canal.

Shahravan et al. (7) examined the root canal wall thickness of the furcation area of the mesiobuccal roots in 100 maxillary first and second molars using the stereomicroscopy technique. The assessment was performed at three sections of the CEJ, and 2 and 4 mm below the CEJ. It was observed that the thickness of the MB1 root canal wall was significantly greater than that in the MB2 root canals in the maxillary first molars; however, there was no significant difference in the dentin wall thicknesses of the MB1 and MB2 root canals of the maxillary second molars. The findings of their study are consistent with those of the present study, and the only difference is that they used the stereomicroscopy technique, while the CBCT technique was used in the present study. The stereomicroscopy technique is an in vitro method, while the CBCT can be used in vivo. Correa et al. (12) compared the accuracy of CBCT in measuring dentin thickness of the danger zone through a direct measurement of dentin thickness under a stereomicroscope and found no significant difference between these two methods. Accordingly, CBCT can be a technique with high accuracy for measuring the dentin wall thickness in the danger zone. Flores et al. (25), too, confirmed the use of CBCT to measure dentin thickness. The statistical analysis method used by Shahravan et al. (7) was different from that adopted in the present study, which would explain the inconsistency of the findings. The limitation of their study, as confirmed by the authors, was that they were not accurate enough in their evaluations, which might have resulted in possible errors.

Endodontic treatment outcomes can be enhanced by gaining a full understanding of the complicated root canal system. The results of the present study contribute to a better understanding of the root canal system of the mesiobuccal root in maxillary molars. Due to the high prevalence of MB2 root canals in maxillary molars and given the narrower wall of the MB2 root canal in comparison to the MB1 root canal, great attention should be paid to the preparation techniques and the minimal residual dentin of the MB2 root canal. When preparing and shaping this root canals, highly tapered instruments (8) and other aggressive instruments, such as Gates-Glidden drills (26, 27), should be used with caution, and safe methods, such as anti-curvature filing technique, are recommended when using manual and rotary instruments.

One limitation of the present study is that the analysis was confined to the critical zone of the furcation area and not the entire root. A full root assessment is a valid recommendation for future research.

CONCLUSION

Considering the lower thickness of the dentinal wall in the MB2 root canal compared with the MB1 root canal in the maxillary first and second molars, the anti-curvature technique should be used to prepare this root canal to reduce the risk of strip perforation. On the other hand, it is recommended that highly tapered instruments and other aggressive instruments, such as Gates-Glidden drills, should be used with caution in these root canals.

Disclosures

Conflict of interest: The authors deny any conflicts of interest related to this study.

Ethics Committee Approval: The research proposal was reviewed and confirmed by the ethics committee of Kerman University of Medical Sciences, Kerman, Iran. The Ethics Committee reference number: IR.KMU.REC.1394.509.

Peer-review: Externally peer-reviewed.

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