Dentine thickness in buccal roots of maxillary first premolars following preparation with three techniques

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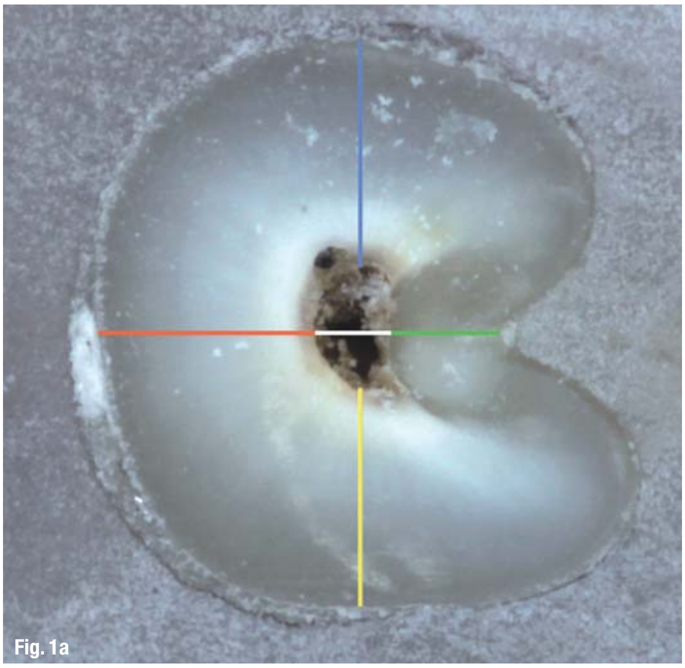

Figs. 1a & b_Image of the transversal cut of a MFP buccal root prepared with K3 G-Pack. Pre-preparation showing the measurements taken: lingual dentine thickness (green line), buccal dentine thickness (red line), proximal a and b (blue and yellow lines), bucco lingual canal diameter (white line; a). Same image after preparation (b).

_Introduction

Coronal and root fractures in teeth are the third major cause of dental loss after caries and periodontal disease, being responsible for 4.3 % of endodontic failures.[1] Of these, maxillary premolars account for more than half of the fractured teeth.[2,3] Some etiological factors reported are dentine dehydration due to endodontic treatment, unique anatomic features, loss of dentine structure due to caries, access preparation and excessive canal preparation. Although some studies have demonstrated that neither dehydration nor endodontic treatment altered the mechanical properties of dentine, it is worth mentioning that the loss of structural integrity owing to caries, previous restorative work or access preparation can predispose teeth that have been endodontically treated to fracturing at a greater frequency than teeth with vital pulps.[4–6] Moreover, this predisposition increases proportionally with the amount of dentine removed.[7]

The type of tooth, canal-wall thickness, root-canal diameter and cross-canal shape may be associated with an increased risk of root fracture following endodontic treatment. In addition, the instruments selected and preparation technique, as well as the size of the master apical file, may also be responsible for possible fracture either during or after endodontic treatment.[8] Finally, irregularities within the internal or external root morphology or sites with small dentine thickness are able to produce areas of strength concentration, which could be critical factors contributing to the initiation and propagation of root fractures.[9, 10]

Maxillary first premolars (MFPs) have ovoid roots with a mesiodistal diameter narrower than that of the buccolingual and display variable radicular configuration and external grooves. Among these grooves is the furcation of the buccal root, which is referred to as a developmental depression, and extends longitudinally over the lingual aspect from the furcation towards the apex. Previous studies on dentine thickness in the buccal root of MFPs demonstrated that the smallest dentine thicknesses were found in the lingual wall and had average values of 0.81 to 1.31 mm, depending on the study.[11–13]

The anatomical factors and operative procedures used are particularly important, given that MFPs are the most prone to fracture.[3,4] Even though these fractures can be caused by many factors, they are often the result of inappropriate preparation owing to a lack of knowledge regarding dentine thickness, as well as to poor file selection.

One of the main objectives of root-canal preparation is to shape and clean the root-canal system effectively whilst maintaining the original configuration; however, traditional stainless-steel instruments often fail to achieve the tapered root-canal shapes needed for adequate cleaning and filling. Therefore, NiTi rotary instruments were introduced to improve root-canal instrumentation, create continuously tapered preparations and shorten working time. These entailed the development of features such as non-cutting tips, radial lands, different cross-sections and superior resistance to torsional fracture with varying tapers.[14] In an earlier study, it was observed that the taper of the preparation and the files chosen could be contributing factors to the generation of craze lines and dentinal defects. It was also demonstrated that these defects could increase the risk of future fracture.[10]

Morphometric studies have shown that the thickness of the lingual wall in buccal roots of MFPs is less than 1 mm on average in instrumented canals.[15] This confirms our previous findings and should be taken into account.[13] Related to this, it is important to note that in prosthetic and endodontic procedures, it is generally agreed that a dentine thickness greater than 1 mm should always remain.[16] The purpose of this study was to evaluate dentine thickness in the buccal root of MFPs both pre- and post-preparation using three different rotary canal instrumentation techniques.

_Materials and methods

The sample consisted of 24 MFPs with two well-formed roots and mature apices without visible apical resorption. The teeth were carefully selected to have a length of between 20 and 22 mm and the furcation located not more than 8 mm from the cemento-enamel junction. The teeth were obtained from the Department of Endodontics, Faculty of Dentistry, University of Buenos Aires. These were treated according to safety protocols established by the University of Buenos Aires, and were kept in solution with equal parts of alcohol and glycerine until use. The teeth were divided into three groups according to the instrumentation technique utilised: (a) K3 G-Pack (SybronEndo) was used for group 1 (n = 8); (b) ProTaper (DENTSPLY Maillefer) for group 2 (n = 8); and (c) RaCe (FKG) for group 3 (n = 8). The teeth were embedded in acrylic resin in a similar way to that previously used for the Bramante muffle.[17]

A vacuum-forming machine was used to create a clamp of plastic resin, which allowed the tooth to be moved back to its original position once sectioned. The blocks were sectioned perpendicular to the larger axis of the tooth using a precision saw (IsoMet Plus) at approximately 2 mm apical to the furcation. Each cut was photographed (Canon; macro 100 mm, 1:1, 3,000 x 4,000 pixels) pre- and post-canal instrumentation.

All buccal root-canal preparations were performed in a crown-down fashion in the following sequence for each group:

_K3 G-Pack: 25.12, 25.10, 25.08, 25.06 and 25.04;
_ProTaper: S1, S2, F1, F2 and F3;
_Easy RaCe: 40.10, 35.08, 25.06 and 25.04.

All samples were frequently irrigated with 2.5 % sodium hypochlorite. Canals were dried with paper points.

The pre- and post-preparation photographs were analysed with the ImageJ pro-

Table 1_Mean values and SE of each of the measured groups pre- and post-preparation.
(LDT: Lingual dentine thickness; BDT: Buccal dentine thickness; BLCD: Buccolingual canal diameter.)

Preparation technique	Variable	Pre-preparation		Post-preparation		Variation	Probability
		Mean	SE	Mean	SE		
K3 G-Pack	LDT (mm)	1.09	0.10	0.96	0.11	-13 %	0.0490
	BDT (mm)	1.25	0.10	1.14	0.12	-9 %	0.0323
	BLCD (mm)	0.34	0.04	0.52	0.06	+52 %	0.0003
	Proximal a (mm)	1.51	0.11	1.45	0.12	-4 %	0.3504
	Proximal b (mm)	1.58	0.12	1.51	0.10	-4 %	0.1374
	Area (mm^2)	0.16	0.04	0.25	0.04	+56 %	0.0010
Pro Taper	LDT (mm)	1.02	0.06	0.94	0.04	-8.5 %	0.0192
	BDT (mm)	1.17	0.02	1.10	0.03	-6.3 %	0.0057
	BLCD (mm)	0.36	0.05	0.53	0.03	+47 %	0.0004
	Proximal a (mm)	1.40	0.05	1.31	0.05	-6.8 %	0.0153
	Proximal b (mm)	1.32	0.07	1.24	0.06	-6.4 %	0.0076
	Area (mm^2)	0.15	0.03	0.24	0.03	+60 %	< 0.0001
RaCe	LDT (mm)	1.07	0.07	0.98	0.08	-9.2 %	0.0119
	BDT (mm)	1.19	0.06	1.10	0.07	-8 %	0.0282
	BLCD (mm)	0.37	0.05	0.52	0.05	+40%	0.0012
	Proximal a (mm)	1.29	0.04	1.24	0.04	-4 %	0.0444
	Proximal b (mm)	1.38	0.06	1.31	0.06	-5 %	0.0319
	Area (mm^2)	0.21	0.07	0.30	0.08	+42 %	0.0003

Table I

gram (http://rsbweb. nih.gov/ij), and measurements of the following variables were taken:

a) lingual dentine thickness (LDT);
b) buccal dentine thickness (BDT);
c) proximal dentine thickness a;
d) proximal dentine thickness b;
e) buccolingual diameter of the canal (BLCD);
f) canal area.

The mesial and distal aspects were grouped together for the purpose of this study and named proximal dentine thickness a and b (Figs. 1a & b).

_Statistical analysis

Statistical analysis was carried out using InfoStat Professional 2010 (FCA-UNC). The Student's t-test was used for comparisons of paired samples between pre- and post-preparation images, and the Kruskal–Wallis non-parametric test was utilised for unpaired samples. $P < 0.05$ was considered to be statistically significant.

_Results

Comparison between paired samples

Mean values and the standard error (SE) were taken pre- and post-preparation for each group and instrumentation technique. Then, the pre- and post-preparation variation was calculated for each value found (Table 1).

K3 G-Pack group: Significant differences between pre- and post-preparation values were observed in LDT ($P = 0.0490$) and BDT ($P = 0.0323$), as well as in the BLCD ($P = 0.0010$).

ProTaper group: Significant differences between pre- and post-preparation values were observed in all the variables examined. These were LDT ($P = 0.0192$), BDT ($P = 0.0057$), BLCD ($P = 0.0004$), proximal dentine thickness a ($P = 0.0153$), proximal dentine thickness b ($P = 0.0076$) and canal area ($P < 0.0001$).

RaCe group: Significant differences between pre- and post-preparation values were observed in all the variables examined. These were LDT ($P = 0.0119$), BDT ($P = 0.0282$), BLCD ($P = 0.0012$), proximal dentine thickness a ($P = 0.0444$), proximal dentine thickness b ($P = 0.0319$) and canal area ($P = 0.0003$).
Comparison between independent groups

It was noted that the three preparation techniques had similar effects, inasmuch as they all provoked a thinning of the dentine walls and an increase in the canal diameter after preparation.

_Discussion

Owing to its anatomical complexity, the endodontic treatment of pathologies affecting MFPs remains a challenge for the clinician. Knowledge of the internal anatomical relationships is fundamental for canal preparation. In addition, several external anatomical characteristics must be taken into account, such as the sulcus and furcation grooves and cracks, and in particular the relationship that exists between them and the variations in dentine thickness. It has already been established that the more grooves there are on the surface of the root and the deeper and more extensive they are, the greater the variations observed in the internal anatomy of the root canals will be.[18]

In a previous study on dentine thickness in MFPs, it was demonstrated that dentine became thinner in the area corresponding to the presence of external grooves.[19] In addition, a high-resolution computed tomography analysis showed that the changes that occur in the canal configuration after preparation depend more on the original canal anatomy than on the instrumentation technique chosen.[20] Therefore, it is fundamental for the clinician to be aware of anatomical variations.

The reported dentine thickness of buccal roots in unprepared teeth varies among authors. Tamse et al.[11] and Katz et al.[15] found meanvalues of less than 1 mm in the lingual wall, whereas Bellucci'smean values were more than 1 mm, with the latter study coinciding with our findings.[12,21] In agreement with earlier studies, the mean values we found in the buccal wall were larger than 1 mm and greater than in the lingual wall on average.[12,22] However, it should be noted that although the dentine thickness was greater than 1 mm on average, in 11 samples this value was less than 1 mm (Table 1).

All three groups revealed a mean dentine thickness in the lingual wall of the buccal root of 0.96 mm after instrumentation, with 15 of 24 samples showing a wall thickness of less than 1 mm after canal preparation. In an earlier investigation on mandibular molars in which rotary instrumentation and a similar method of assessment was used, it was demonstrated that pre-instrumentation dentine thickness was the major factor in determining post-instrumentation dentine thickness.[23] As seen in our studies, the smallest dentine thicknesses were found in the furcal wall.

Li et al.[24] analysed changes in the configuration of MFPs with five classes of canal configuration, including the one used in our study (Weine Type III). They used the F3 ProTaper file as the master apical file, and found an increased canal volume and surface and canal straightening towards the inner aspects of the curved parts. Although these authors reported a good instrumentation effect, 40.7 % of walls were untouched.

Pilo et al.[22] reported a mean of 0.82 mm for furcation wall thickness after instrumentation. However, the difference with our study may be attributed to the use of different instrumentation techniques.

Figs. 2a & b_Photomicrograph of buccal root prepared with ProTaper. Pre-preparation (a). Same image post-preparation (b). It can be observed that the instrument tends to lean against the furcation wall (yellow arrow).

Fig. 2a

Fig. 2b

Figs. 3a & b_Photomicrograph of buccal root prepared with RaCe. Pre-preparation (a). Same image post-preparation (b). The yellow arrow clearly shows the canal area prepared by the instrument, leaving other areas untouched (red arrow).

The preparation of the coronal third of the canal is fundamental to access of the apical third. This allows for optimal debris removal and overall better irrigation, preparation and obturation. However, the thickness of dentine walls must be preserved, as any thinning will predispose the roots to perforation and radicular fracture. It should be born in mind that during any type of preparation, especially rotary instrumentation, the instruments tend to wear down the thinnest walls that correspond to the furcation groove in the MFPs (Figs. 2a & b).[15] In the present study, we measured dentine thickness 2 mm apical to the furcation, as this corresponds to the critical area where fissures commence after root-canal treatments. Although the three instrumentation systems used in this study are not consistent in taper, they were chosen for being in current use in clinical practice.

The present results were similar for all three systems used in this study, with dentine thickness decreasing as canal area increased significantly (Table 1). On analysing the slices after surgical preparation, it was noted that all instruments tended to produce rounded preparations, while leaving some areas of the walls untouched (Figs. 3a & b).

The thickness of the dentine walls decreased by 4 to 13 % and the most important changes were found in the furcation wall, thus confirming earlier studies that indicated that instruments tend to lean on this wall and thereby cause greater thinning of the area in question (Table 1).[13, 25, 26] This may be attributed to the corono-radicular axis and the divergence of the canal, which leads to the instrument leaning on top of the furcation wall. It is therefore very important to record the measurements of the lingual wall after preparation. We obtained mean values smaller than 1 mm for all the groups, as previously seen in other studies.[15] Thus, owing to the presence of the furcation groove, these values were smaller than the recommended 1 mm dentine thickness.[27] Related to this, previous studies have shown that the risk of fracture increases as more dentine is removed.[8]

We agree with Robbins that, ideally, the canals of MFPs should not be enlarged after endodontic obtu-

_about the authors

roots

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ration.[28] If the use of posts is required, they must be modified to fit the canal.[29] Indeed, excessive post-space preparation weakens root strength and increases the risk of root perforation, especially with premolars and mandibular incisors.[8] In our study, the BLCD and its area revealed increases of greater than 40 %, as seen in earlier studies (Table 1).[30,31]

Anatomy and topography studies are necessary, since the data obtained will facilitate the determination of which instruments and techniques to use in any given case. Some authors maintain that endodontic preparation should respect the anatomy of the canal. However, this may be very difficult to carry out if the practitioner does not have the appropriate technology to adapt his or her clinical reality to the anatomical and topographical needs. In fact, the clinician must generate a new anatomy after canal preparation, which means that he or she has to assess the limits, thickness and shape of the new contours. Consequently, the measurements of this new dental piece will be critical for any future restorative treatment and for its return to mandibular function. Future studies involving strength patterns should follow anatomy and topography studies, and as a result lead to new lines of investigation.

_Conclusion

In the present study, we chose three instrumentation systems used in clinical practice. In the case of an MFP, the clinician should be aware of the original anatomy in order to obtain cleanliness and proper obturation with fewer instruments. Dentine thickness in the buccal roots of MFPs decreases significantly after preparation, with the furcation wall being the most affected area. The three preparation techniques had similar results. The BLCD increased significantly after preparation.

_Clinical recommendations

Owing to the particular anatomical characteristics of MFPs, their treatment remains a real therapeutic challenge. Anatomical aspects such as the furcation groove in buccal roots, proximal grooves and dentine thickness have to be taken into account when planning endodontic and prosthetic procedures. Ideally, the canals should not be additionally enlarged after endodontic preparation._

Editorial note: A complete list of references is available from the publisher.