Braz Dent J (2005) 16(1): 23-29 ISSN 0103-6440

Root Canals and Apical Foramina of the Buccal Root of Maxillary First Premolars with Longitudinal Sulcus

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In the present study, periapical radiographs were analyzed to investigate the number of canals of the buccal root of maxillary 1st premolars with longitudinal sulcus, and compare the number of apical foramina observed on the radiographs to that revealed by scanning electron microscopy (SEM). Thirty-nine human maxillary 1st premolars had their crowns and palatal roots removed and the root canals (C) were explored with endodontic files until the tip of the instrument was visualized exiting the apical foramen/foramina (AF). Radiographs were taken with files inside the root canals and the specimens were classified as follows: 1C/1AF; 2C/2AF; 1C/2AF; 2C/1AF. Apices were examined under SEM and the number of apical foramina (considering those measuring ≥80 µm in diameter) was recorded. Only 17.1% (n=6) of the specimens had 1C/1AF; 77.2% (n=27) had 2AF in which 42.9% (n=15) had 2C and 34.3% (n=12) had 1C; 5.7% (n=2) had 2C/1AF. SEM examinations showed that 46.1% (n=18) of the specimens had 2AF; 23.1% (n=9) had 1AF; 23.1% (n=9) had 3AF; 7.7% (n=3) had 4AF. Radiographic and SEM findings for the number of AF coincided in 62.8% of the cases. A buccal longitudinal sulcus in the maxillary 1st premolar is usually accompanied by total bifurcation (42.9%) or apical bifurcation (34.3%) of the root canal. SEM identified a statistically higher number of apical foramina than radiographs ($p<0.01$).

Key Words: root canals, apical foramina, maxillary 1st premolar, longitudinal root sulcus, scanning electron microscopy.

INTRODUCTION

Better prognoses in endodontic treatment can only be achieved if dentists have thorough knowledge of the internal anatomic configuration of teeth. Lack of knowledge of internal dental anatomy and anatomic variations may lead to errors in identification, instrumentation and obturation of root canals (1).

Some classic studies on internal dental anatomy (2,3) have provided important data for better understanding of Endodontics, thus contributing to the success of root canal therapy.

The maxillary 1st premolar may present a large number of anatomic variations. Root canal treatment of this tooth is difficult because of the direction and longitudinal depression of its roots, the different configurations of the pulp chamber and the difficulty in visualizing the apex on radiographs (1).

The maxillary 1st premolar usually has two roots that may be either separated or partially or totally fused. Less frequently, this tooth may have a third root and, consequently, a third canal. When it has one palatal and two buccal roots (a mesiobuccal and a distobuccal), the maxillary 1st premolar is called a "minimolar" (4). Different root configurations have been described (1,3,5-10) based on the number of roots (Table 1). The maxillary 1st premolar usually has two canals, a buccal and a palatal, even when the tooth has only one root (4). Table 2 shows the number of root canals in the maxillary 1st premolar as described in several studies (1,5-7,11-15), as well as the number of specimens and technique used. The rate of occurrence of a maxillary 1st premolar with

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three root canals is very low, ranging from 0.5% (12) to 7.5% (5). According to the studies summarized in Table 2, the possibility of a maxillary 1st premolar having 3 root canals, even when there is only one buccal root, should be considered.

Rodrigues et al. (16) found 6 teeth with sulcus on the buccal surface of the buccal root while studying a sample of 113 maxillary 1st premolars. They concluded that teeth with a larger number of sulcus and with deeper and more extensive sulcus show more internal root variations.

Pinheiro Júnior et al. (17) examined the internal and external anatomy of 79 maxillary 1st premolars with three distinct roots or roots with sulci that conferred trifurcation characteristics. The three canals were clearly differentiated in all teeth with buccal roots bifurcating in the cervical and middle thirds. When roots bifurcated in the apical third, the specimens had one single buccal canal up to the point of bifurcation and two distinct canals from that point on.

Unsuccessful endodontic treatment of maxillary 1st premolars may be associated with a second canal in the buccal root being overlooked and hence not accessed, prepared and obturated. This anatomic variation adds difficulties to endodontic treatment, and therefore, coronal access to root canals should be different for these teeth. When maxillary premolars have three canals, two of them are buccal and one is palatal (17). Therefore, access should have a triangular shape, with the base of the triangle on the buccal side, similar to the access shape for maxillary molars.

The purposes of this study were to assess radiographically the number of canals of the buccal root of maxillary 1st premolars with longitudinal buccal sulcus, and to compare the number of apical foramina (AF) found on radiographs to that revealed by scanning electron microscopy (SEM).

Table 1. Percentage of roots in maxillary first premolars.

Author	Year	1 root (%)	2 roots (%)	3 roots (%)
Pucci and Reig (3)	1945	43.0	52.6	2.4
De Deus (5)	1973	35.5	61.0	3.5
Pécora et al. (1)	1991	55.8	41.7	2.5
Chaparro et al. (6)	1999	40.0	56.7	3.3

MATERIAL AND METHODS

Thirty-nine human maxillary 1st premolars with fully developed roots, no root fractures and a longitudinal sulcus on the buccal surface of the buccal root were selected. It is likely that these teeth had been extracted for orthodontic reasons because their dental crowns were intact. Age, sex and ethnical group of the patients from whom the teeth were extracted were not taken into consideration in this study.

The teeth were collected from Health Stations and dental offices in the countryside of the State of Rio Grande do Sul, Brazil. Up to the laboratory phase, the teeth were kept in saline inside labeled plastic containers with individual caps, which had been previously distributed to the dental offices and health stations enrolled in the study.

Table 2. Percentage of root canals in maxillary first premolars.

Author	Year	Technique	n	1 canal (%)	2 canals (%)	3 canals (%)
Hess (11)	1925	Vulcanite casting	269	19.5	79.3	1.2
Pineda and Kuttler (12)	1972	Radiography	259	50.1	49.4	0.5
Carns and Skidmore (13)	1973	Resin casting	100	9.0	85.0	6.0
Sutalo and Njemirovskij (14)*	1980	-	1216	42.5	54.0	3.5
Della Serra and Ferreira (7)	1981	-	260	19.5	79.3	1.2
Pécora et al. (1)	1991	Clearing	240	17.1	80.4	2.5
De Deus (5)	1992	Clearing	108	8.3	84.2	7.5
Kartal et al. (15)	1998	Clearing	300	8.7	89.7	1.6
Chaparro et al. (6)	1999	-	159	40.0	56.7	3.3

n=number of specimens *This study focused on maxillary first and second premolars.

Dental crowns were removed close to the cementoenamel junction by pressing the tooth against a plaster abrasion tool (VH, Araraquara, SP, Brazil). The roof of the pulp chamber was completely removed and access to the root canals was obtained without touching the floor of the chamber. Distinct palatal roots were amputated using a low-speed double-faced diamond bur (KG Sorensen, Barueri, SP, Brazil) with abundant water cooling, so that only the buccal root with the longitudinal sulcus was left.

Root canals were explored with #06, #08, and #10 endodontic files (Dentsply-Maillefer, Ballaigues, Switzerland) after being irrigated with 1% sodium hypochlorite using a Luer-Lock syringe with a 25/5 gauge dental needle (Ibrás, Campinas, SP, Brazil).

Once apical patency was obtained - that is, the tip of the endodontic instrument was visualized exiting the apical foramen/foramina - radiographs were taken. An x-ray unit (Gnatus, Ribeirão Preto, SP, Brazil) operating at a 0.8-s exposition time was used. Ektaspeed plus EP-21P films (Kodak, Rochester, NY, USA) were processed in a portable film processor with immersion in the developer solution (Kodak, São José dos Campos, SP, Brazil) for 1 min and in the fixation solution (Kodak, São José dos Campos, SP, Brazil) for 10 min. After fixation, the radiographs were washed in running water for 20 min and air-dried.

Radiographic images of the buccal roots were examined and classified by two observers, according to the number of root canals and apical foramina, as follows: 1 root canal and 1 apical foramen (1C/1AF) - when the observer identified 1 root canal centralized in the root and the endodontic file up to 1 mm passing the apical foramen; 2 root canals and 1 apical foramen (2C/1AF) - when 2 root canals were identified with two distinct endodontic files exiting the same foramen. The existence of 2 root canals was confirmed by the distance between the endodontic files along the canals, since one file was inserted into the mesiobuccal canal and the other into the distobuccal canal; 1 root canal and 2 apical foramina (1C/2AF) - when 1 root canal bifurcated at the apical third and formed 2 foramina in the apical region. In this case, the endodontic files overlapped along most of the root canal toward the apex, one mesially and the other distally; 2 root canals and 2 apical foramina (2C/2AF) - when 2 distinct root canals were identified with two endodontic files running parallel to each other and exiting from 2 independent foramina.

A water-cooled carborundum disc was used to section 3-5 mm of the apical portion of the buccal root perpendicularly to the long axis of the tooth. The root apices were soaked in 2.5% sodium hypochlorite solution for 3 h and then successively placed in 70, 90 and 99% alcohol, for 5 h in each. The specimens were mounted on labeled stubs using graphite powder and clear nail polish, with their apical surfaces facing upward. Five to six apices were mounted on each stub. Marks were made with a carborundum disc on the stub surface to allow for identification of each specimen individually on the screen.

SEM analyses were carried out at the Laboratório de Microscopia Eletrônica da Universidade Luterana do Brasil, Canoas, RS, Brazil. A MED 020 coater (BAL-TEC, Balzers, Liechtenstein) was used to metal coat the specimens with a 150-Å-thick gold-palladium layer. The apices were examined under a XL20 scanning electron microscope (Phillips, Eindhoven, Netherlands) operating at 15 KV and with magnifications that allowed for visualization of the entire specimen on the screen, in such a way that the apical foramina could be clearly visualized and their diameter determined. The longest axis of each apical foramen was measured in micrometers using of a tool provided by computer software.

Many teeth exhibited a great number of easily identifiable small-sized foramina, which were not considered in the study. Only foramina measuring ≥80 µm in diameter were included and designated as apical foramina.

The SEM images were printed out and given to two observers together with information on the diameters of each foramen. The observers classified the specimens as having 1, 2, 3 or 4 AF.

The results of radiographic and SEM examinations were tabulated and analyzed statistically using the Wilcoxon nonparametric test.

RESULTS

Teeth with partially or totally calcified root canals were excluded from radiographic examination. In some cases, the exploratory files did not achieve the full length of the root canal, but were very close to the apical foramen and so the classification of the specimen was obvious.

Table 3. Radiographic examination - number of root canals and apical foramina in the buccal root of maxillary 1st premolars with longitudinal sulcus.

Number of canals (C) and apical foramen/foramina (AF)	Number of specimens
1 C /1 AF	6 (17.1%)
1 C /2 AF	12 (34.3%)
2 C /1F AF	2 (5.7%)
2 C /2 AF	15 (42.9%)
Total	35 (100%)

Table 4. SEM - number of apical foramina in the buccal root of maxillary 1st premolars with longitudinal sulcus.

Number of apical foramina	Number of specimens
1	9 (23.1%)
2	18 (46.1%)
3	9 (23.1%)
4	3 (7.7%)
Total	39 (100%)

Table 5. Comparison of the number of apical foramina (AF) in maxillary 1st premolars with longitudinal sulcus visualized by radiographs and SEM.

	SEM			
Radiographs	1 AF	2 AF	3 AF	4 AF
1 AF	6 (17.1%)	–	1 (2.9%)	1 (2.9%)
2 AF	2 (5.7%)	16 (45.7%)	7 (20.0%)	2 (5.7%)

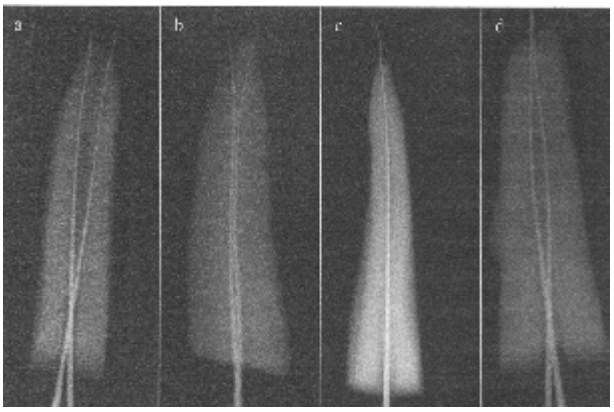

Figure 1. Radiographs of the buccal roots of maxillary 1st premolars with longitudinal sulcus: a - 2C/2AF; b - 1C/2AF; c - 1C/1AF; d - 2C/1AF.

Of the 39 teeth examined, 35 could be classified according to the number of root canals and apical foramina based on the radiographic findings (Table 3). Two apical foramina were observed in the majority of the specimens (77.2%). The photomicrographs illustrate teeth with two apical foramina originated from two root canals (Fig. 1a), two apical foramina originated from one canal (Fig. 1b), a single canal and a single foramen (Fig. 1c), and teeth with one apical foramen resulting from the fusion of two root canals (Fig. 1d).

The number of apical foramina identified under SEM is shown in Table 4. Most of the specimens (46.1%) presented two AF (considering those measuring ≥80 µm). Figures 2a to 2d illustrate specimens with 1, 2, 3 and 4 AF, respectively.

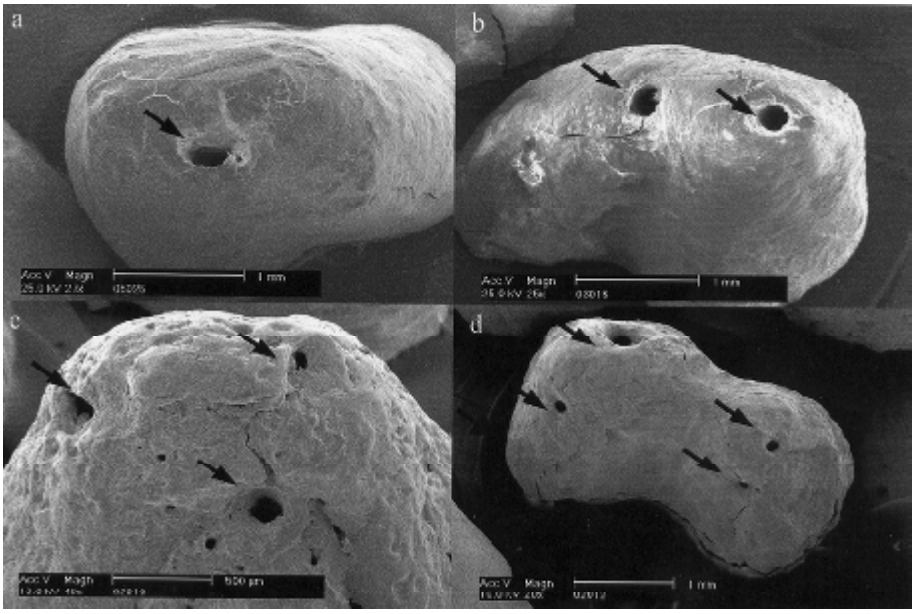

Figure 2. Photomicrographs of the apical portion of the buccal root of maxillary 1st premolars with longitudinal sulcus: a - 1 AF; b - 2 AF; c - 3 AF; d - 4 AF.

The number of AF visualized by radiographs and SEM of the 35 specimens analyzed is shown in Table 5. The methods identified the same number of AF in only 62.8% of the specimens. SEM identified a higher number of AF than radiographs in 31.5 % (n=11) of the cases, whereas radiographs identified a higher number of AF in only 5.7% (n=2) of the specimens.

DISCUSSION

The root canal system is a part of the tooth that cannot be directly visualized by the dentist. Radiographs are helpful for the visualization of root anatomy, but are limited because they provide two-dimensional images of a three-dimensional object (6,15). Therefore, accurate knowledge of root anatomy is an important ally to radiographic resources, tactile sense and operator's clinical experience, thus contributing to the success of endodontic treatment. Incomplete disinfection of the root canal system is frequently a cause of failure of endodontic treatment (18).

This study investigated the buccal root of maxillary 1st premolars with longitudinal sulcus because it has been reported (16) that the internal anatomic variations of these teeth are closely associated to the presence of a sulcus in their roots.

It is important to point out that the bifurcation of canals in the buccal root of maxillary 1st premolars often results in extremely thin and atresic canals, which are difficult to access, explore and obtain apical patency. Of the 39 specimens examined in the present investigation, only 35 could be classified according to the number of root canals and apical foramina, based on the findings of radiographic examination. It was not possible to access the canals and hence the AF in only one specimen. For the other three specimens, it was possible to identify the existence of two root canals up to a certain point along the root length, but the number of apical foramina could not be determined radiographically (Fig. 3a). For one of these cases, SEM revealed 2 AF (Fig. 3b), one of which was totally obliterated by cement (Fig. 3c). SEM was able to reveal 1 to 4 AF for the root canals seen on radiographs, while radiographs themselves revealed only 1 or 2 AF.

Of the studied specimens, 77.2% of the canals, regardless of the number of roots, had 2 apical foramina. In teeth with 1C/2AF (34.3% of the cases), cleaning and shaping of the root canal must be performed in a way that guarantees hermetic sealing of the canal in the apical portion of the root. Additionally, the existence of 2C/2AF (42.9%) requires that the shape of the access cavity be changed from an elongated oval shape wider in the buccolingual direction to a triangular shape with the base on the buccal side, similar to the access cavity for maxillary molars (17).

The second buccal canal in teeth with 2C/1AF (5.7%) may be considered a recurrent canal, and so endodontic success depends on the hermetic apical sealing of only one of the buccal canals because they join each other before the point where obturation should end (19).

The results of this study are relevant because the radiographic imaging method is widely reported in the literature for investigation of internal dental anatomy (12). Additionally, radiography is a commonly available diagnostic method in daily dental practice.

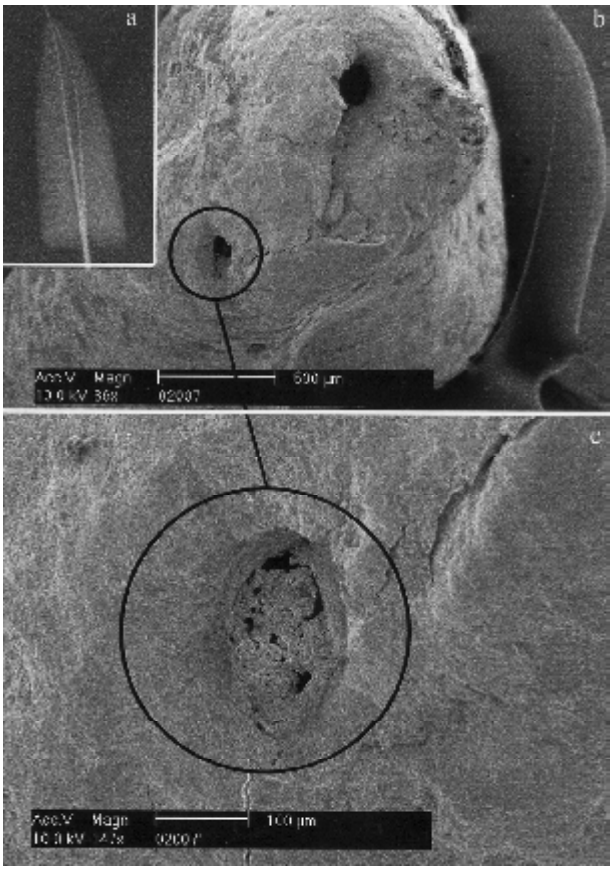

Figure 3. a: Radiograph of 2 root canals whose number of apical foramina could not be assessed radiographically; b: Photomicrograph of the same tooth showing 2AF, one of which was calcified (c).

The classification of internal anatomy utilized in this study does not follow Vertucci's classification (20), which is routinely referred to in the literature. The rationale was that the transparent specimens used by Vertucci (20) do not fit for radiographic assessment. Therefore, teeth were classified as having 1C/1AF, 2C/1AF, 2C/2AF and 1C/2AF; the number of canals was determined when either 1 or 2 canals were visualized along most of the root length, and the number of apical foramina was determined by the visualization of the tip of the file exiting either 1 or 2 foramina.

Because of the aforementioned limitations of radiographic examination, SEM was also used to assess the number of AF. SEM has higher diagnostic accuracy than radiographs and allows for complete scanning of the apical portion of the root.

Although this study did not investigate accessory foramina, it is worth mentioning how often they were identified by SEM, which confirms that the maxillary 1st premolar is the tooth that most often presents an apical delta (5).

The diameter of an AF may range from 100 to 520 µm (2). A minimum diameter of 80 µm was accepted in this study because the buccal root of maxillary 1st premolars with longitudinal sulcus presents smaller foramina due to canal constriction, the sulcus being the most frequent cause of root canal bifurcation.

Radiographic and SEM findings for the number of AF coincided in 62.8% of the specimens. However, SEM was able to identify a greater number of foramina in 31.5% (10) of the specimens because this method provides a detailed visualization of the apical root topography. In 20% of the cases, radiographs showed 2AF while SEM revealed 3AF. These findings confirm that maxillary 1st premolars with 2 root canals are similar to the maxillary 1st molars. Although these teeth have 2 buccal roots, they frequently have 3 canals - one in the distobuccal root and two in the mesiobuccal root (the mesiobuccal and the mesiolingual canals).

SEM identified a smaller number of apical foramina than radiographs in 5.7% (n=2) of the cases, at a 1:2 ratio. SEM revealed 2 foramina in one of the specimens, but one of them measured only 58 µm and was thus classified as an accessory foramen rather than an AF. In the other specimen, 2 canals were visualized with endodontic files running along the root length. However, apical patency was not obtained in one of the canals, which was 1 mm short of the radiographic apex. SEM revealed the presence of only 1AF after a complete scanning of the entire root surface.

The comparison of our results with those of previous investigations cannot be done because most of available studies on endodontic anatomy report only the number of roots and root canals. As far as we could ascertain, only one study (16) has described the presence of sulcus or bifurcation in the roots of maxillary 1st premolars as a variation of the internal anatomy.

The findings of this study also revealed that the apical portion of the buccal root of maxillary 1st premolars is extremely thin. Therefore, further research should investigate at what level the lateral apical preparation should stop in these roots to avoid endodontic treatment failure.

In conclusion, the presence of a longitudinal sulcus in the buccal root of the maxillary 1st premolar predisposes to either total (42.9%) or apical (34.3%) bifurcation of the root canal; radiographic and SEM findings for the number of apical foramina agreed in 62.8% of the cases; the number of apical foramina visualized by SEM was higher than that identified by conventional radiographs in 31.4% of the cases, which shows that SEM provides better diagnostic accuracy.

RESUMO

Avaliamos radiograficamente o número de canais da raiz vestibular de 1° pré-molares superiores com sulco longitudinal vestibular, e comparamos com microscopia eletrônica de varredura (MEV) quanto ao número de forames apicais (FA). As coroas e raízes palatinas de 39 dentes foram amputadas e os canais radiculares (C) explorados com lima endodôntica fina até suas pontas serem visualizadas apicalmente. As raízes foram radiografadas com as limas em seu interior e classificados pelo critério a seguir: 1C/1FA; 2C/2FA; 1C/2FA; 2C/1FA. Os ápices da raiz vestibular foram seccionados e preparados para MEV. Os números de FA (≥80 µm) foram obtidos. A avaliação radiográfica demonstrou que 17,1% (n=6) das raízes apresentaram 1C/1FA 77,2% (n=27) tinham 2FA, sendo 42,9% (n=15) oriundos de 2C, e 34,3% (n=12) de 1C; 5,7% (n=2) apresentaram 2C terminando no mesmo FA. Em MEV, 46,1% (n=18) dos ápices apresentaram 2FA; 23,1% (n=9), apenas 1FA; 23,1% (n=9), 3 FA; e 7,7% (n=3), 4 FA. Houve correlação entre o diagnóstico radiográfico e MEV quanto ao número de FA em 62,8% dos casos. O sulco longitudinal vestibular no primeiro pré-molar superior predispõe à bifurcação total (42,9%) ou apical (34,3%) do canal radicular; sendo o método radiográfico estatisticamente inferior ($p<0.01$) à MEV no diagnóstico de FA.

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Accepted June 24, 2003