# Anatomical evaluation of the root canal diameter and root thickness on the apical third of mesial roots of molars

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ORIGINAL ARTICLE

# Anatomical evaluation of the root canal diameter and root thickness on the apical third of mesial roots of molars

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**Abstract** The purpose was to determine the diameter of the main root canal and wall thickness in the apical dentin in mesial roots of maxillary and mandibular molars. Forty mesiobuccal and mesial root specimens were sectioned horizontally at 1, 2 and 3 mm from the apex, and measured at each top surface by using optical microscopy to an accuracy of ×20 magnification. The anatomical parameters were established as the following points of reference: AB, two points connected by a line from the outer edge of the mesial wall to the outer edge of the distal one through the center of the root canal to measure the thickness of the root and mesiodistal diameter of the root canal (CD). A second line (EF) was designed to evaluate the diameter of the root canal in the buccolingual direction. All data were summarized, and values were assessed statistically by ANOVA and Bonferroni multiple comparisons. The buccolingual (BL) root canal diameters at 1, 2 and 3 mm in the mandibular and maxillary molars were greater than in the mesiodistal (MD), showing statistically significant differences ($p < 0.05$). The MD root thicknesses at 1, 2 and 3 mm in mandibular and maxillary molars were statistically significant ($p < 0.05$). The lowest value to 1 mm from the apex in the mandibular molars was 1.219 mm and the highest at 3 mm from the root apex in maxillary molars was 1.741 mm. The BL diameters in maxillary and mandibular molars were higher than the MD diameter. The thickness (MD) of maxillary and mandibular molars decreased as a function of apical proximity.

**Keywords** Dental anatomy · Dentinal thickness · Molars · Root canal diameter

## Introduction

The success of endodontic treatment demands knowledge of the apical root canal anatomy (Vertucci 2005). Morphological analysis shows that canals are oval-shaped or irregular in the apical third and present their largest diameter at the buccolingual aspect (Wu et al. 2000a, b; Wu and Wesselink 2001; Martos et al. 2009). Generally, the thicknesses of radicular dentine are greater on the lingual surfaces of the roots, and wall thickness is thin in the apical third (Bellucci and Perrini 2002).

Wu et al. (2000a, b) described a high prevalence of oval canals in the apical portion of human tooth roots. Kerekes and Tronstad (1977), evaluating maxillary and mandibular molars, found that the largest diameter of the root canal at the various levels might be larger than the narrowest part of the root. With regard to fillings, some authors confirmed that many of the canal areas (especially in the apical region) are not touched during canal preparation because of their oval or irregular configurations (Wu et al. 2000a, b; Weiger et al. 2006). Uninstrumented recesses may be left in oval canals after preparation and often may not be completely obturated (Wu et al. 2000a, b).

The apical portion of the root canal system can harbor apical microflora that can promote and sustain periradicular inflammation (Sundqvist 1992, 1994). The removal or reducuction of residual pathogens at this portion is

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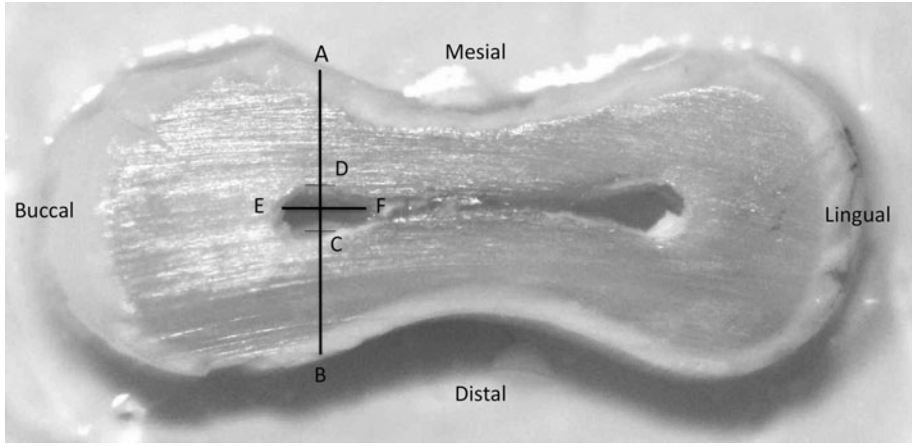


**Fig. 1** Reference points used in the study. *AB* Root thickness, *CD* mesiodistal diameter of the root canal, *EF* buccolingual diameter of the root canal

imperative during apical chemomechanical preparation (Sjögren et al. 1990; Nair et al. 1990; Baugh and Wallace 2005).

The aim of this study was to investigate the canal diameters and root thicknesses in the apical region of the mesial roots of the maxillary and mandibular molars.

## Materials and methods

In this study 40 nonrestored human teeth of the maxillary and mandibular arch (first molars) with completely formed apices were used. These teeth were obtained from the school at our institution, and were devoid of root resorption or hypercementosis. The dental specimens used in this study and the research project were obtained in accordance with the Ethics Committee. Twenty teeth were selected for each group—mandibular and maxillary. The specimens were carefully subjected to manual cleaning to remove calculus and any remnants of periodontal tissue, and kept in buffered formalin solution until analysis.

Maxillary and mandibular molars roots were sectioned horizontally, 0.30 mm thick, with a diamond disk (KG Sorensen, São Paulo, Brazil) at 1, 2 and 3 mm from the apex for a total of 120 samples. The specimens selected were fixed on a microscopic slide so that the anatomical parameters could be calculated. In total, 60 sections for maxillary and 60 for mandibular molars at 1, 2 and 3 mm were studied.

Examinations of the root sections from each tooth were performed with a Leitz Optical magnifying glass (Ernst Leitz GmbH, Wetzlar, Germany) at ×20 magnification and confirmed with a caliper. Two examiners who were trained and calibrated for the study performed the evaluations. Parameters were established as the following points of reference: (1) to measure the thickness of the dentin, two points connected by a line from the outer edge of the mesial wall to the outer edge of the distal (AB); (2) to measure the mesiodistal diameter of the root canal, two points were connected by a line from the mesial and distal border of the root canal (CD); (3) to evaluate the diameter of the root canal in the buccolingual direction a second line (EF) was designed by making a line from the buccal and lingual/palatal area of the root canal (Fig. 1).

**Table 1** Mean diameter and standard deviations (± SD), in millimeters, for a mesiobuccal root canal of the maxillary molars at the three levels tested

| | Maxillary molars with a single canal in the mesiobuccal root | | | | |
|---|---|---|---|---|---|
| | Mesiobuccal root canal | | | | |
| | Mesiodistal diameter | | | Buccolingual diameter | |
| | *n* | Mean | ±SD | Mean | ±SD |
| 1 mm | 20 | 0.166 | ±0.07 | 0.319 | ±0.18 |
| 2 mm | 20 | 0.226 | ±0.10 | 0.426 | ±0.18 |
| 3 mm | 20 | 0.252 | ±0.11 | 0.613 | ±0.26 |

The canal diameters and root thickness (mm) were determined, and their means and standard deviations were calculated at each level for each group of specimens. The values were compared by factorial analysis of variance (ANOVA) using SPSS software (SPSS Incorporated, Chicago, IL). When $F$ tests were significant, post-hoc Bonferroni multiple comparison intervals were further performed to identify statistically homogeneous subsets ($p = 0.05$). We also tested intra-examiner agreement to eliminate bias by using kappa statistics.

## Results

The values expressed in millimeters for root canal diameters and root thickness are summarized in Tables 1, 2, and 3, respectively. The data measured by the evaluators had a

**Table 2** Mean diameter and standard deviations (± SD), in millimeters, for mesial root canal of mandibular molars at the three levels tested

| | Mandibular molars with two canals in mesial root | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mesiobuccal root canal | | | | | Mesiolingual root canal | | | | |
| | Mesiodistal diameter | | | Buccolingual diameter | | Mesiodistal diameter | | | Buccolingual diameter | |
| | *n* | Mean | ±SD | Mean | ±SD | *n* | Mean | ±SD | Mean | ±SD |
| 1 mm | 20 | 0.188 | ±0.08 | 0.607 | ±0.47 | 20 | 0.204 | ±0.11 | 0.329 | ±0.15 |
| 2 mm | 20 | 0.238 | ±0.08 | 0.763 | ±0.50 | 20 | 0.256 | ±0.11 | 0.422 | ±0.23 |
| 3 mm | 20 | 0.267 | ±0.09 | 0.882 | ±0.63 | 20 | 0.300 | ±0.12 | 0.515 | ±0.24 |

**Table 3** Mean thickness (mm) of the mesiobuccal root of maxillary molars and mesial root of mandibular molars

| | Maxillary molars | | | Mandibular molars | | |
|---|---|---|---|---|---|---|
| | Mesiodistal diameter | | | Mesiodistal diameter | | |
| | *n* | Mean | ±SD | *n* | Mean | ±SD |
| 1 mm | 20 | 1.425 | $\pm0.46^{A,a}$ | 20 | 1.219 | $\pm0.37^{A,b}$ |
| 2 mm | 20 | 1.619 | $\pm0.48^{B,a}$ | 20 | 1.435 | $\pm0.41^{B,a}$ |
| 3 mm | 20 | 1.741 | $\pm0.50^{C,c}$ | 20 | 1.619 | $\pm0.43^{C,a}$ |

The different capital letters indicate significant differences in the maxillary or mandibular molars at three levels ($p < 0.05$). Multiple comparisons shown by the same small letters indicate no significant differences in the maxillary and mandibular molars at three levels ($p < 0.05$)

kappa index for the mandibular and maxillary molars of 0.608 and 0.643, respectively. These values characterize a substantial link between the interpretations given by the evaluator's table (Landis and Koch 1977).

The mesiodistal (MD) root thicknesses among the different levels tested (1, 2 and 3 mm) for maxillary and mandibular teeth were distinct from one another ($p = 0.006$). In maxillary molars the mesiodistal diameter was different at 1 mm (1.425 mm) in comparison with 2 mm (1.619 mm) and also different at 3 mm (1.741 mm). Similarly, in mandibular molars the mesiodistal diameter was different at 1 mm (1.219 mm) in comparison with 2 mm (1.435 mm) and 3 mm (1.619 mm). There was a clear statistical difference among the three levels of assessment for mandibular and maxillary roots with a lower value at 1 mm and higher one at 3 mm, which is indicated in Table 3 by the capital letter.

Bonferroni multiple comparisons between groups (maxillary and mandibular) in three levels of evaluation (1, 2 and 3 mm) are indicated in Table 3 with lower case letters, showing values statistically similar to the maxillary molar teeth at 1 mm (1.425 mm) and 2 mm (1.619 mm), and mandibular at 2 mm (1.435 mm) and 3 mm (1.619 mm). A lower statistically significant value was found for the mandibular root at 1 mm (1.219 mm) and a higher value for the maxillary root at 3 mm (1.741 mm). The average diameter of the root canal in the maxillary and mandibular teeth was higher in the buccolingual diameter compared to the mesiodistal at the three levels tested.

## Discussion

Successful endodontic treatment demands knowledge of the normal aspects of root canal morphology and correct interpretation of its variations. In this study, 120 cross sections at various levels of the molar roots from adult teeth were examined. The results of this study are almost entirely in agreement with those found by others using equivalent methodology and numbers of samples (Wu et al. 2000a, b; Kerekes and Tronstad 1977). Discrepancy values were only found at the MB root of the molars in their buccolingual diameter where we observed a larger diameter of 1 mm (0.60 mm) and 2 mm (0.76 mm) compared to the values of the mentioned authors, presenting an average of 0.40 and 0.42 mm, respectively.

The apical root canal anatomy, specifically in relation to endodontic treatment, may be more complex than it seems (Vertucci 2005; Martos et al. 2010). In all tested perimeters, we observed that the larger diameter of the root canal was the buccolingual over the mesiodistal, confirming a characteristic oval of the canals in the apical portion of the human tooth (Wu et al. 2000a, b; Kerekes and Tronstad 1977).

Wu et al. (2000a, b) demonstrated that root canals are frequently long ovals in the apical region. These authors defined a long oval canal as one that has a buccolingual diameter larger than its mesiodistal one. These anatomic configurations suggest that apical preparations need to be made in larger sizes than previously recommended because of these uninstrumented extensions in oval canals (Wu and Wesselink 2001; Rödig et al. 2002).

The correlation between MD root thickness and buccolingual diameter is important because the values found allow presupposing enough dentin wear to clean this area.

The buccolingual extension in the root canal was significantly smaller than the MD thickness in the maxillary molars at 1 mm (0.319–1.425 mm), 2 mm (0.426–1.619 mm) and 3 mm (0.613–1.741 mm), as well as in mandibular molars at 1 mm (0.607–1.219 mm), 2 mm (0.763–1.435 mm) and 3 mm (0.882–1.619 mm). An increase of more than two or three files for effective cleaning of the oval canal in this situation would be necessary. Anatomically an exaggerated oval extension of the canal may hinder or even jeopardize mechanical cleaning, enabling bacteria to enter the elongated portion. Hyper-instrumentation in these anatomical conditions may favor a weakening or even cause a perforation of the root apical to this level.

Although this oval configuration may sometimes not be effectively cleaned, a filling completing these sub-instrumented recessions allows sufficient microbial control (Gutmann and Witherspoon 1998). The anatomical complexity of the root canal system allows viable bacteria to exist inside the infected dentinal tubules and recessed canals (Silveira et al. 2010). It is difficult for endodontic files to access these regions; as a result, to disinfect these accessory canals, we can choose the appropriate irrigating solutions such as sodium hypochlorite (at concentrations ranging from 2.5 to 5.25%) and decalcifying solutions during the chemomechanical preparation (Machado-Silveiro et al. 2004; Pérez-Heredia et al. 2006).

We should take greater care in preparing biomechanics when it comes to oval canals, because the extent of apical extension is based on the estimate of the apical canal diameter given by the adaptation of the endodontic file in its original working length; however, this manual detection of the apical zone will depend crucially on their shape and narrowing (Silveira et al. 2008). Paqué et al. (2010) analyzed two- and three-dimensional adaptation of apical files in molars, and observed that its apical adaptation was poor and did not correspond to their original anatomy.

Interestingly, the external shapes of the apical foramen can be categorized as round or oval, but variations of these could be possible, resulting in an asymmetrical shape (Martos et al. 2009, 2010). Although most of the apical foramen is round or oval in shape, Green described the shapes of peripheral contours of the apical foramen as semilunar, serrated, hourglass or asymmetric (Green 1956). At least at a small distance from the root apex (1, 2 and 3 mm), the findings of this study showed geometrically that the internal shape of the canal is closer to oval than round.

These slight variations between the external and internal root apex anatomies could be due to the different ages of specimens, the few groups investigated, the influence of occlusion, the permanent remodeling of the root apex through cementum apposition, and resorption and other factors that could mask or modify the results.

## Conclusion

The results obtained and the analysis conducted in this study led to the conclusion that, in all of the root canal sections, the long canal diameter BL is larger than the short canal diameter MD, and the root thickness is smaller closer to the apex.

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