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Periapical radiographs overestimate root canal wall thickness during post space preparation

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Abstract

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Aim To evaluate differences between anatomic and radiographic measurements of root canal wall thickness (RCWT) after each root canal preparation stage during post placement.

Methodology Twenty mandibular premolars with a single canal were decoronated and the roots embedded in resin using a teflon muffle. Roots were sectioned horizontally at a pre-established level and canals were prepared for post placement. Endodontic hand files were used for root canal preparation, followed by Gates Glidden drills and Peeso reamers. Standardized radiographs and photographs at pre-established measurement levels were taken before preparation, after root canal instrumentation, after Gates Glidden preparation and after Peeso enlargement. All images were digitized and RCWT at the mesial and distal walls measured (IMAGETOOL 3.0). Differences between radiographic and anatomic measurements were analysed with paired *t*-tests. ANOVA was used to compare the percentages of radiographic distortions.

Results Regardless of the time-point evaluated, RCWT determined by radiographs were greater than the respective anatomic measurements ($P < 0.05$). The difference detected at each stage was similar and constant ($P > 0.05$).

Conclusions Throughout preparation for post placement, radiographic images overestimated the RCWT by approximately 25%, regardless of the clinical stage evaluated.

Keywords: post preparation, radiographic images, root canal wall thickness.

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Introduction

Rehabilitation of root-filled teeth may require the use of intraradicular posts to provide retention for permanent coronal restorations. Space for posts is generally created mechanically using rotary instruments (Pilo & Tamse 2000). A conservative approach during post space preparation focused on the preservation of healthy dentine is directly related to the longevity of restored pulpless teeth (Assif & Gorfil 1994). Several studies have demonstrated that reduction of the radicular dentine thickness increases the failure rates of post-retained restorations (Tamse 1988, Kuttler *et al.* 2004, Ricketts *et al.* 2005a, Sathorn *et al.* 2005, Grieznis *et al.* 2006).

Usually the diameter of the preparation should be equal to one-third of the root diameter observed on the radiograph (Johnson *et al.* 1976) and the remaining dentine thickness should not be less than 1 mm (Caputo & Standlee 1976). Despite the fact that these are old concepts, they are still valid as references for the lower limit of residual radicular dentine thickness (Katz *et al.* 2006). Based on this measurement, practitioners can determine the most appropriate bur size to 'safely' remove dentine during post space preparation, leaving at least a 1-mm thickness of residual radicular dentine.

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The most common method used to control the amount of dentinal tissue removed during post preparation is based on measurement of mesial and distal root canal wall thickness (RCWT) in periapical radiographs (Gutmann 1992). However, this method has demonstrated lack of accuracy in determining the actual root anatomy (Raiden *et al.* 2001), as well as lack of precision for a number of dental treatments (Sant'Ana *et al.* 2005, Bruntz *et al.* 2006), especially because of overlapping structures and distortion (Miano & da Silva 1988). In addition, radiographs have the limitation of presenting a two-dimensional image of a three-dimensional object (Raiden *et al.* 2001). Therefore, some details in the root anatomy can be lost or misinterpreted, which may compromise clinical judgment during post space determination, especially in teeth with concavities in the proximal faces, such as premolars and molars (Raiden *et al.* 2001, Kuttler *et al.* 2004). In these teeth, deep and narrow concavities may not be detected by conventional radiographs (Raiden *et al.* 2001). Hence, the radiographic estimation of RCWT is inaccurate. An attempt to follow the established clinical guidelines previously mentioned may not guarantee that the RCWT necessary to avoid root fractures or perforations will remain.

It is important to highlight, however, that periapical radiographs remain as the most reliable clinical tool used for determining the RCWT, as well as the 'safest' amount of dentine that can be removed during root canal preparation for post-retained restorations. Thus, information on the amount and the pattern of distortion in radiographic images during the clinical procedures for post placement would provide useful knowledge and help clinicians to avoid weakening roots during canal preparation.

This study was designed to: (i) determine the differences between radiographic and anatomic RCWT measurements before and after preparation for post placement; and (ii) establish a pattern of radiographic distortion observed during post preparation, if it occurred. The null hypothesis tested was that there are no differences between anatomic and radiographic thicknesses of root canal walls, regardless of the treatment-stage evaluated.

Materials and methods

Experimental design

This laboratory-based study involved a randomized blinded design with 20 teeth selected and prepared for post placement. After each preparation stage (before preparation, after hand instrumentation, after Gates Glidden drills preparation and after Peeso reamer enlargement), standardized photographs and standardized radiographs were taken, and the RCWT (in mm; ±0.01) was determined at pre-established reference points. Thus, each tooth served as its own control. Differences between anatomic and radiographic measurements were recorded, and data in millimetres or in percentage of disagreement were analysed. All endodontic procedures were carried out by a single operator and all the measurements by two blinded examiners. Teeth were considered as experimental units for statistical analysis.

Specimen selection and preparation

Initially, 34 second mandibular premolars were cleaned of debris and stored in 0.2% sodium azide (NaN_3) (E. Merck, Darmstadt, Germany) at 4 °C until use. Proximal and buccal radiographs were taken to select teeth with single canals. A digital calliper was used to select 20 teeth exhibiting root canal width ranging from 0.8 to 1.2 mm (mesial aspect) and 0.6 to 1.0 mm (buccal aspect) at a 5 mm level from the apex on the radiographs (Wu *et al.* 2000).

Considering that the post length should be at least that of the crown (Sorensen & Martinoff 1984), the crown height of each specimen was measured taking as references the end of the buccal cusp and the most apical point of cementum–enamel junction at the buccal face. This value was transferred to the post drills in the subsequent phases of the study to ensure that the drill penetration was as deep as the crown height determined individually (Raiden *et al.* 2001). The crowns were removed using a carborundum disc under running water at the most apical point of the cementum–enamel junction at the buccal face (Fig. 1a).

Roots were embedded in polystyrene resin using a teflon muffle (Wu *et al.* 2005) to ensure their correct positioning during the experiment (Fig. 1b), as this model allows the comparison of subsequent preparations using the tooth as its own control. Embedded roots were then sectioned horizontally using a low-speed saw (Isomet 1000; Buehler Ltd., Lake Bluff, IL, USA) under water cooling. Debris was eliminated with profuse irrigation of 2% freshly prepared NaOCl for 1 min without the use of instruments. The cross-section was carried out 1 mm coronally to the level previously determined by the crown height value. This

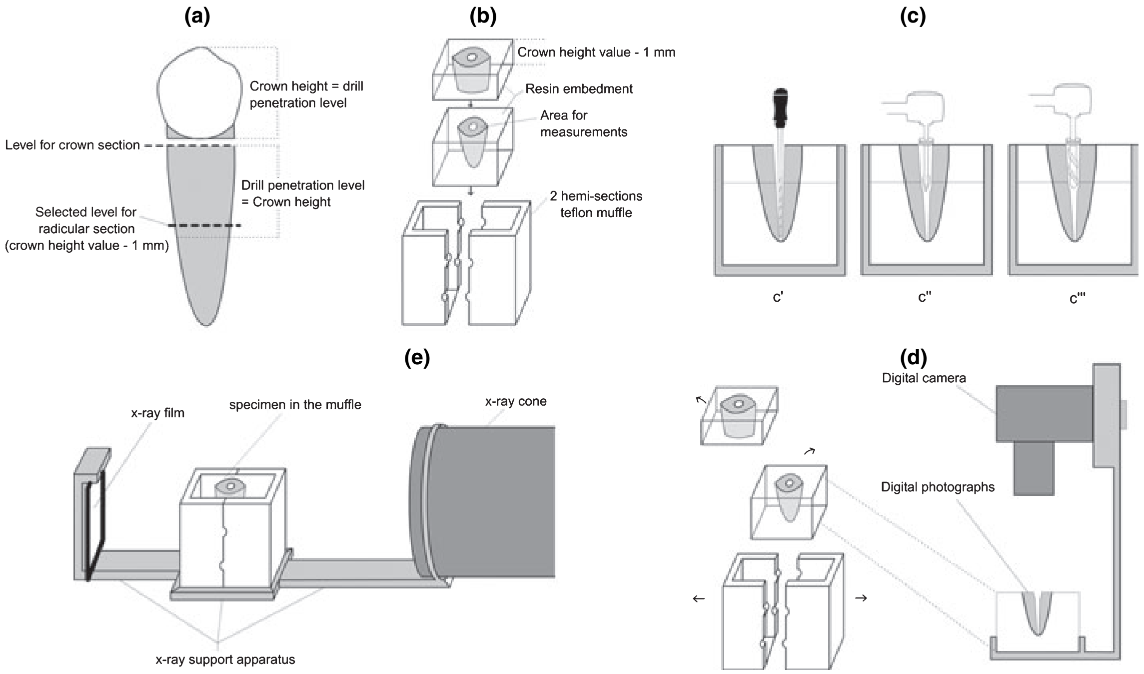

Figure 1 Schematic illustration of the experimental design used. (a) Tooth preparation and decoronation; (b) root embedment and cross-section; (c) sequence of root canal preparation for post; (c′) hand instrumentation; (c″) Gates Glidden drills; (c‴) Largo Peeso reamers; (d) muffle disassembling and support apparatus for digital photographs; (e) support apparatus for standardized radiographs.

level was selected as the point for radiographic and anatomic measurements (Fig. 1a) and corresponded to the most apical level of the preparation before the tapered end left by the drills (Raiden *et al.* 2001).

Root canal instrumentation and post space preparation

The root canals were prepared using Flexofile instruments (Dentsply Maillefer, Ballaigues, Switzerland) with hand instrumentation. Instruments sizes 15–40 were used to create an apical stop 1 mm short of the canal terminus (Fig. 1c′). A step-back preparation with 1 mm increments was performed up to instrument size 70.

Post preparation was initiated by enlarging the root canals with Gates Glidden drills (Dentsply Maillefer) sizes 1 and 2 (ISO size 050 and 070, respectively). Finally, Peeso reamers (Dentsply Maillefer) sizes 2 and 3 (ISO size 070 and 090, respectively) were used to refine the post hole.

No pressure was applied against the root canal walls when Gates Glidden drills and Peeso reamers were used. Each drill was gauged with silicon stops to ensure that preparations were as deep as the crown lengths previously measured (Fig. 1c″,1c‴). Debris generated after each instrument was rinsed with 2 mL of freshly prepared 2% sodium hypochlorite. After preparation, root canals were thoroughly dried with paper points.

Images capture and measurements

Four stages were chosen for the evaluation: before preparation (baseline), after root canal instrumentation, after use of Gates Glidden drills and after use of the Peeso reamers. Digital photographs and radiographs were taken to allow comparison between the anatomic and radiographic RCWT.

The root sections were disassembled from the muffle and the coronal face of the apical section was selected for the photograph to obtain the anatomic RCWT measurements. The specimen was set in an apparatus for standardized photographs (Fig. 1d). Photographs were taken from each sectioned tooth along with a millimetre scale under 10× magnification with a digital camera (Sony Cybershot DSC 707; Sony Corporation, Tokyo, Japan). Images were saved in tagged image file format (TIFF) and transferred to the software

IMAGETOOL for Windows 3.0 (San Antonio Dental School, University of Texas Health Science, TX, USA), where the anatomic RCWT was measured. The lowest RCWT (in mm; ±0.01) on the mesial and distal walls were determined and recorded.

Standardized parallel radiographs were taken as follows: the root sections were reinserted in the muffle, which was connected to a plastic support for standard radiographic exposures. The use of this device allowed reproducible radiographs to be taken at different times without changing the original position of the tooth (Fig. 1e). Parallel bucco-lingual radiographs were taken using Ultra-speed Kodak films (Eastman Kodak Company, Rochester, NY, USA) and a 70-kV X-ray machine (Dabi Atlante, Ribeirão Preto, São Paulo, Brazil), with an exposure time of 0.4 s and a constant focus to film distance of 20 cm. All films were scanned along with a millimetre scale and images processed as for the anatomic measurements. Radiographs showing double lines on either the root or the canal surface had as reference point the smallest RCWT recorded. Radiographic and anatomic RCWT measurements were carried out at the same level in each tooth. All analyses were performed in duplicate by two calibrated examiners working independently. The final recorded value was the average value of the two readings.

Statistical analyses

Differences between radiographic and anatomic measurements at each clinical stage were analysed using the paired *t*-test. ANOVA was used to compare the percentage of distortions observed in the radiographic measurements amongst the clinical stages evaluated. The significance level was set at 5%. All analyses were performed with SPSS, version 12.0.1. (SPSS, Chicago, IL, USA).

Results

Table 1 shows results (in mm) for the disagreements between radiographic and anatomic RCWT after each stage. A statistically significant difference was detected when the radiographic RCWT measurements were compared with the anatomical RCWT measurements ($P < 0.05$), where radiographs revealed greater thickness values at all stages (Table 1).

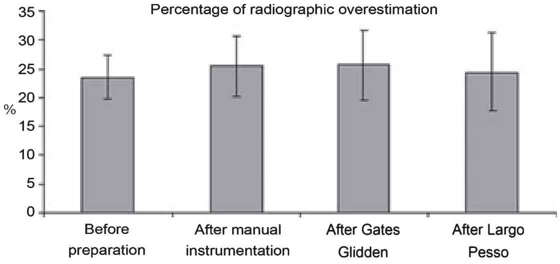

Figure 2 Percentage (Avg ± SE) of radiographic overestimation before and after each root canal preparation. There were no significant differences amongst the stages evaluated ($P = 0.979$).

The percentage of radiographic overestimation after each step of the root canal preparation was determined (Fig. 2). ANOVA showed that the percentages of radiographic overestimation were not significantly different amongst the stages analysed ($P > 0.05$).

Discussion

This study was designed to assess discrepancies between anatomic and radiographic RCWT in mandibular premolars after the use of several instruments commonly employed during the canal preparation for post-retained restorations. The muffle model (Wu *et al.* 2005) was used to allow standard radiograph to be exposed at each stage.

Periapical radiographs overestimated the RCWT. This phenomenon was observed by Raiden *et al.* (2001) in a study evaluating maxillary premolars and the present findings on mandibular premolars corroborate this previous study. The external anatomy of these tooth groups may explain the findings. Normally, the proximal surfaces of premolars have concavities or notches that reduce the distance between the outer and

Table 1 Comparison between anatomic and radiographic RCWT after each stage ($n = 20$)

Clinical stage	Radiographic RCWT (mm)	Anatomic RCWT (mm)	Mean difference (mm)	*P*-value
Before preparation	1.62 ± 0.26	1.32 ± 0.18	0.30 ± 0.20	<0.001
After manual instrumentation	1.50 ± 0.25	1.21 ± 0.18	0.29 ± 0.25	<0.001
After Gates Glidden	1.40 ± 0.24	1.14 ± 0.20	0.26 ± 0.27	<0.001
After Peeso	1.29 ± 0.20	1.07 ± 0.20	0.22 ± 0.25	<0.001

inner root surfaces, but do not decrease substantially the volume of the proximal root canal wall detected by periapical radiographs. In maxillary premolars, deep and narrow notches at the proximal surfaces are frequently observed (Bellucci & Perrini 2002), whereas in mandibular premolars the concavities are more shallow and wide (Lu *et al.* 2006). This is a reasonable explanation for the observation of a radiographic overestimation ranging from 30 to 35% in maxillary premolars (Raiden *et al.* 2001), whilst the amount of overestimation observed in the present study was 25% (on average) in mandibular premolars. Although the concavities and anatomic characteristics may be different when comparing maxillary and mandibular premolars, the amount of radiographic overestimation detected in both studies was similar.

Mandibular premolars were chosen in the present study because they present less variation in external anatomy of proximal surfaces than the maxillary counterparts. Although 46% of mandibular premolars have complicated root canal anatomy, which may contribute to deep grooves in the proximal root surfaces, those complications are more prevalent in the apical area, i.e. 6 mm from the apex (Lu *et al.* 2006). In fact, most of these teeth have shallow concavities in the coronal/medium level of the root (Lu *et al.* 2006). Furthermore, considering that most of tooth types, except for maxillary central incisors, have some degree of proximal indentation (Bellucci & Perrini 2002, Kuttler *et al.* 2004), the radiographic RCWT overestimation in mandibular premolars is likely to be much closer to other tooth groups than observed in maxillary premolars.

As periapical radiographs are the most commonly used method to study the anatomy of the root (Gutmann 1992) and to evaluate the amount of dental tissue that could be removed during post hole preparation, the identification of a radiographic overestimation pattern may be a useful clinical tool.

The amount of radiographic overestimation in RCWT measurement procedures has never been described. Raiden *et al.* (2001) demonstrated that the radiographic value is actually higher than the anatomical RCWT measurements; however, no attempt to determine the amount of radiographic overestimation was given by those authors. In the present study, the percentage of radiographic overestimation was calculated; whether the use of subsequent instruments to prepare the root canal could change the pattern of radiographic distortion was also evaluated. Different instruments lead to distinct amounts of dentine removal, mainly in the proximal inner surfaces (Pilo & Tamse 2000), which might influence the RCWT observed radiographically. However, a pattern of radiographic overestimation was observed regardless of the instrument used. These findings reinforce the concept that the anatomy of the root external surface and overlapping of anatomic structures are determinant factors in the radiographic overestimation. This is a clinically relevant observation considering the fact that clinicians usually have no information about the last instrument used to prepare the root canal. During treatment, the root canal can be prepared either manually (hand files) or mechanically (rotary files, Gates Glidden drills or Peeso reamers). If the amount of overestimation remains the same regardless of the instrument used, it is possible to identify a constant pattern for the distortion and therefore to determine a coefficient for overestimation correction.

Theoretically, according to the present data, if parallel radiographs are taken from selected teeth for post hole preparation, a reduction of about 25% in the radiographic RCWT would be appropriate to correct the value observed considering the anatomic proximal wall thickness. Therefore, it is possible to suggest a simple formula which could help clinicians to overcome the risk of root weakening and/or perforation during post preparation:

$$\mathrm{AV} = \mathrm{RV}/1.25$$

where AV is the anatomic value and RV is the radiographic value.

Many teeth are lost because of excessive dentine removal during post preparation, leaving the root prone to fractures or perforations (Ricketts *et al.* 2005b). Considering that parallel radiographs overestimate the anatomical RCWT in teeth with different degree of proximal indentation, any attempt to reduce the risk of permanent root damage during instrumentation would enhance safety and should be taken in consideration by clinicians.

Additional laboratory studies should be carried out to evaluate other tooth groups to assess whether the same pattern occurs. Understanding the overestimation of RCWT may enable practitioners to use evidence in their decision-making when using radiographs during clinical procedures.

Conclusions

There was a pattern of approximately 25% of radiographic overestimation during proximal RCWT determination regardless of the instrument used to prepare the root canal in mandibular premolars. The identification of a radiographic overestimation pattern may assist a conservative approach during root canal preparation for post-retained restorations.

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