Influence of working length and foraminal enlargement on foramen morphology and sealing ability

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ABSTRACT

Aim: The present study evaluated the influence of the working length and foraminal enlargement on the sealing ability and anatomy of the apical region of the root.

Materials and Methods: Fifty-five roots were divided into three groups: G1, instrumentation 1 mm short of the major foramen; G2, instrumentation in the limit of the apical foramen; and G3, instrumentation 1 mm beyond the foramen. All groups were prepared using nickel-titanium rotary files and obturated with AH Plus and Gutta-percha. Photomicrographs were taken using a scanning electron microscopy (SEM) before instrumentation, after instrumentation with each file, and after root canal filling. Moreover, bacterial microleakage with Enterococcus faecalis was performed.

Results: The results were analyzed using Mann–Whitney, Friedman, Kruskal–Wallis and Kaplan–Meier tests at a significance level of 5%. The cemental canal was uninstrumented in G1. No statistical differences regarding foramen deviation was observed when compared G2 and G3 (P > 0.05). SEM analysis showed that G2 and G3 resulted in good apical foramen obturation. Microleakage showed no statistically significant differences between all of the groups tested.

Conclusions: Under the conditions of this study, it can be concluded that foraminal enlargement resulted in more apical deviation; however, no differences in bacterial microleakage was observed among the experimental groups.

Key words: Apical foramen, endodontic, foraminal enlargement, root canal preparation

Apical patency is a technique in which the apical portion of the canal is maintained free of debris by recapitulation with a small file through the apical foramen.¹ The most predictable method is to regularly use a so-called patency file during cleaning and shaping procedures. This file can be defined as a small flexible file, which is passively moved through the apical constriction without widening it.²

The passive cleaning of the cemental canal with flexible files without widening the apical constriction has been recommended for endodontic treatment. However, in cases of apical periodontitis, recognizing the presence of microorganisms in the apical portion of the canal and even in the lesion itself³⁵ has contributed to the acceptation of larger apical preparations⁶ and cleaning, debridement, and enlargement of the apical foramen⁶ during root canal instrumentation because it can overcome the potential limits of irrigation in the apical area, optimizing root canal disinfection.⁶⁻¹⁰

Achieving a larger apical diameter during foraminal enlargement, however, might lead to apical transportation. This transportation of the apical foramen can lead to complications in subsequent cleaning and filling procedures.¹¹ To date, numerous studies have examined canal transportation using different file systems.¹²,¹³ However, to the best of the author’s knowledge, no studies have been performed to evaluate the anatomy and sealing ability during foraminal enlargement. The purpose of this

Received : 28-05-15
Review completed : 17-07-15
Accepted : 12-02-16
study was to evaluate the influence of the working length and apical foraminal enlargement on the anatomy of the apical foramen and the sealing ability after root canal filling with AH Plus and Gutta-percha.

MATERIALS AND METHODS

The present research was approved by the Ethics Committee in Research of the Piracicaba School of Dentistry, State University of Campinas, protocol number 080/2009. Fifty-five intact human molar teeth were used in this study. Preoperative mesiodistal and buccolingual radiographs were taken for each root to confirm the canal anatomy. The criteria for tooth selection included: No visible root caries, no fractures, no cracks, no signs of internal or external resorption or calcification and a completely formed apex. Roots canals with no more than 5° of curvature were considered straight and were included in this study.

The palatal roots of maxillary molars were decoronated to standardize the root length to 11 mm. The samples were randomly divided into three groups (n = 15) according to the different working lengths: G1, instrumentation 1 mm short of the major apical foramen; G2, instrumentation in the limit of the major apical foramen; and G3, instrumentation 1 mm beyond the major apical foramen. In all groups, electronic tooth length measurements were carried out before root canal preparation using the electronic apex locator Root ZXII (J. Morita, Kyoto, Japan) using a previously described in vitro model.14 All groups were prepared using the crown-down technique using k3 rotary files (Sybron Endo, Orange, CA, USA). The electric motor was calibrated to run at a speed of 300 rpm with a torque of 2 Ncm according to the manufacturer’s instructions. Cervical and middle thirds were enlarged with instrument sizes of 25, 0.10 taper and 25, 0.08 taper. Apical rotary instrumentation was performed by enlarging the root canal to at least three times the size of the first manual file that bound at working length, according to the different groups, with a 0.06 taper.

Before the use of each new instrument, the canals were filled with 0.5 mL of 2% chlorhexidine (Biodinâmica, Ibiporã, PR, Brazil) as the auxiliary chemical substance. After the use of each instrument, 5.0 mL of saline solution was used as the irrigating solution. Before obturation, a final flush with 10 mL of 17% ethylenediaminetetraacetic acid (Biodinâmica) was performed. Then canals were dried using paper points (Dentsply, Ballaigues, Switzerland).

The canals were obturated with Gutta-percha and AH Plus (Dentsply), using single-cone obturation technique. In G1, a medium nonstandardized master Gutta-percha point (0.06 taper) was selected and cut at its apical third to the size of the master apical file preparation; in G2 and G3 the point was cut two sizes larger than the size of the master apical file preparation in order to prevent apical extrusion of the Gutta-percha. In G1, the point was fitted at the working length and seated in the root canal. In G2 and G3 the point was fitted 2 mm before the apical foramen and seated in the root canal. A Touch ’n Heat plugger (SybronEndo) was selected and prefitted to its binding point at 8 mm short of the working length, with aid of a silicon stop. Touch ’n Heat was used at a power setting of 7. The preheated plugger was inserted, and the apical pressure was maintained for nearly 10 s, allowing the apical segment of the Gutta-percha to cool under this force to compensate for Gutta-percha shrinkage; the plugger was then removed.

For microscopic analysis, the specific parameters of 3 kV, and ×50 magnification were used, in a scanning electronic microscope (JSM 5600 Lv, JEOL, Tokyo, Japan). The specimens were mounted on specific metallic stubs to prevent their movement and to allow the evaluation to be made parallel to the long axis of the foramen. Photomicrographs were taken before instrumentation, after instrumentation of the apical foramen by each file, and after root filling. Consequently, five images were taken for each root. The samples were placed in the same position to record the standardized images of root apex. The teeth was carefully analyzed at scanning electron microscopy (SEM) at a magnification of ×50 to the identification of the major foramen of each root. The opening of the largest diameter found at the root apex identified the major apical foramen.15 A grid system was used to evaluate the photomicrographs that consisted of a circle divided into four equal segments, with radii projecting to intersect the canal surface; the center of the circle was located in the center of the root canal16 [Figure 1]. Each segment was measured according to a scoring system [Supplementary file 1]. A single examiner, who was trained and calibrated for the study, performed the blind evaluations of 225 images. Approximately, 10% of the sample was re-evaluated to verify intra-examiner reproducibility. The examiner agreement was >0.89 (89%) according to the Kappa test. All image procedures were performed using AutoCAD 2008 software (Autodesk, Mill Valley, California, USA).

![Figure 1: The grid system used for the canal widening assessment](image-url)
sterilized in a gamma irradiation chamber for 24 h at 27°C with a 14.5 KGy dose. Glass flask apparatus was prepared for this experiment, and consisted of two separate chambers; the lower part was filled with brain heart infusion broth (BHI) so that only the root apex was in contact with the broth, whereas the coronal part was immersed in BHI containing Enterococcus faecalis (ATCC 29212) to investigate bacterial microleakage. The flasks were then incubated at 37°C in an atmosphere of 10% CO₂ and microbial growth was checked daily, by the appearance of turbidity in the BHI broth, for 60 days. The colony-forming units were counted, and the purity of the cultures was confirmed by Gram staining, catalase production, colony morphology on BHI agar 1 blood, and by the use of a biochemical identification kit (API 20 Strep, BioMérieux; Marcy-l’Etoile, France). The positive controls (n = 5) were filled with Gutta-percha only and tested with bacteria, whereas the negative controls (n = 5) were sealed with nail varnish and cyanoacrylate to test the seal between the chambers.

The results were analyzed using BioEstat 5.0 software (Mamirauá, Tefé, AM, Brazil). Mann–Whitney was used to compare differences between different groups regarding apical deviation. Friedman test was used to detect differences in treatments across multiple test attempts. Kruskal–Wallis was used to analysis of bacterial leakage results. Kaplan–Meier test was used to measure the fraction of bacterial living for a certain amount of time after root canal filling.

RESULTS

The samples in G3 showed the best results for cementum removal after apical enlargement with the first and second sized files beyond the first file that bound at working length. The SEM images of these samples showed more scores of 2 (enlargement by two quarters of the circumference of the circle) and 4 (enlargement by four quarters of the circumference of the circle). However, after the third file was used, there were no differences between G2 and G3 [Table 1]. G3 presented more apical foramen deviation compared to G2, with more scores of 2 (deviation by two-quarters of the circle) and 3 (deviation by three-quarters of the circle) [Table 2 and 3, Figure 3].

In the bacterial microleakage test, all positive controls showed bacterial microleakage within 72 h. No penetration of bacteria was observed in the negative controls during the observation time of 60 days. The Kaplan–Meier probabilities for the experimental groups are shown in Figure 2. No significant differences were observed amongst the experimental groups (P > 0.05).

DISCUSSION

The apical portion of a root canal is often not cleaned as well as the middle and coronal portions after root canal preparation with various instruments and techniques. Bacteria located in anatomic complexities such as dentinal tubules, irregularities, and ramifications, especially in the apical region can be protected from the effects of instruments and chemical substances used in the main canal. Insufficient cleaning of the apical portion might cause periapical inflammation. One explanation for this is that the master apical file used is too small to achieve sufficient apical debridement. It has been reported that increasing the apical enlargement might enhance the debridement of the apical portion of a root canal. In addition, larger apical size preparations have also demonstrated greater microbial reduction in the apical third.
Figure 2: Kaplan–Meier (95% confidence interval) curves of the sealed root canals for the different groups in the bacterial microleakage test

Table 3: Percentage of foramen obturation scores

| Group | S† | Percentage of obturation |
|-------|----|--------------------------|
|       | Score 0 | Score 1 | Score 2 | Score 3 | Score 4 |
| Group 1 (1 mm short foramen) | a | 40 | 0 | 20 | 6.7 | 33.3 |
| Group 2 (in foramen) | b | 93.3 | 0 | 6.7 | 0 | 0 |
| Group 3 (1 mm beyond foramen) | b | 86.7 | 13.3 | 0 | 0 | 0 |

†Significance=Different letters indicate statistically significant differences at 5%, aScore 0=Four quarters of the circumference of the circle filled, bScore 1=One quarter of the circumference of the circle unfilled, cScore 2=Two quarters of the circumference of the circle unfilled, dScore 3=Three quarters of the circumference of the circle unfilled, eScore 4=Four quarters of the circumference of the circle unfilled

Figure 3: Representative scanning electron microscopy appearance of apical foramen before instrumentation, after instrumentation of the apical foramen by each file, and after root filling (a) instrumentation 1 mm short of the major apical foramen; (b) instrumentation in the limit of the major apical foramen and; (c) instrumentation 1 mm beyond the major apical foramen
of the apex. According to this concept, the cemental canal should not be instrumented and thus, will not be cleaned. Studies on periapical healing associated with teeth presenting periapical lesions showed that the best result was obtained when the cemental canal and the apical foramen were widened more than the patency instrument.

Apical widening may result in a severe periapical inflammatory reaction that is deleterious to the healing process. However, the results of an in vivo histological study involving apical and periapical tissues following root canal therapy showed that apical foramen widening favored the healing outcome of induced chronic periapical lesions in the teeth of dogs. Borlina et al. also reported a high incidence of microorganisms in the groups in which apical foramen widening was not performed, and acute inflammation was also present. Therefore, performing apical widening of the cemental canal and the apical foramen may enhance the potential for apical healing because it removes a greater amount of contaminated cementum and promotes more favorable conditions for healing. Other advantages of this procedure are that it minimizes the risk of loss of length, eases irrigation in the apical third of the canal, and improves the tactile sensing of the clinician during apical shaping. Apical enlargement ensures cleanliness and improves the quality of canal filling.

Despite all the advantages of apical widening, one commonly reported disadvantage is the possibility of postoperative pain related to physical trauma in the periapical region. It is suggested that even the use of small patency files through the apex can cause a periapical acute inflammatory response and severe postoperative pain. However, a recent study demonstrated that a foraminal enlargement instrumentation technique resulted in the same postoperative pain and necessity for analgesic medication when compared to a nonenlargement technique. Corroborating with this study, Arias et al. did not find any statistically significant differences in the incidence of postoperative pain using controlled over instrumentation, a much more aggressive technique than just maintaining apical patency. Moreover, Torabinejad et al. found that unintentional overextension of the files does not affect the incidence of postoperative pain.

In this study, the influence of different working length associated with apical widening on the anatomy of the apical foramen and on the sealing ability after root canal filling was evaluated. The findings of the present study showed that working length, instrumentation in the apical foramen (G2) and instrumentation 1 mm beyond the foramen (G3) had no statistically significant differences on apical widening. After the third file was used 46.7% had touched all walls of the cemental canal in G2, and 53.3% had touched the walls in G3. G1, where the instrumentation was made 1 mm short of the major foramen, served as the control because the files did not touch the canal walls, so there was no widening or deviation in the apical foramen.

Instrumentation 1 mm beyond the apical foramen (G3) can promote more deviations from the original foramen anatomy. G3 had 66.7% apical foramen deviation, but this deviation did not affect the quality of obturation. Many factors have been discussed as being contributors to deviations, such as complex canal anatomy, instrument design, instrumentation sequence, operator experience, and the inadequate use of an irrigant. In this study, the use of files with a 0.06 taper could have caused apical foramen deviations as the great taper of the instrument decreases its bending resistance. However, numerous studies have shown that nickel-titanium rotary instruments can effectively produce a well-tapered root canal for sufficient for obturation, with a minimal risk of transporting the original canal.

Although foraminal widening can promote more deviations, microscopic analysis showed that both widening groups (G2 and G3) resulted in good quality apical foramen obturation. G2 showed that 93.3% of the apical foramen was filled, with 86.7% in G. However, statistical analysis of bacterial microleakage showed no statistically significant differences between all tested groups. One of the major concerns regarding performing foraminal widening is the possibility of increased risk of endodontic sealer extrusion. This extrusion through the apical foramen into the periirradicular tissues can increase the risk of tissue irritation or delayed healing. However, according to the results of previous studies, the toxicity of endodontic sealers tends to decrease with time. Hence, despite the transitory irritability that endodontic sealers may cause to periapical tissues, endodontists should evaluate the advantages and disadvantages of sealer extrusion since the nonwidened and nonsealed areas in the apical region may serve as microorganism niches, initiating, or perpetuating an endodontic failure.

Recent studies suggested that root canal instrumentation at apical foramen and 1 mm beyond the foramen can potentially cause cracks on the apical root surface. However, in the present study, no apical cracks was observed. The contradictory results observed between the present study, and the previously mentioned research may be explained by differences in the methodology. Future randomized controlled trials should be conducted to evaluate the effectiveness of foramen widening on the successful outcome of root canal treatment, recognizing the treatment factors that will increase the predictability of endodontic therapy.

Under the conditions of this study, it can be concluded that foramen enlargement resulted in more apical deviation;
however, no differences in bacterial microleakage was observed among the experimental groups.

**Financial support and sponsorship**
Nil.

**Conflicts of interest**
There are no conflicts of interest.

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