Influence of apical preparation technique on root canal disinfection and shaping: literature review

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ABSTRACT

Introduction: Endodontic therapy should reduce the microbial load within the root canals, which can be achieved during chemomechanical preparation (CMP). The purpose of CMP of the root canal system (RCS) is to create a favorable environment for healing. CMP associates the mechanical action of instruments with the use of auxiliary chemical substances. There is no consensus among professionals about what should be the diameter of the apical foramen after CMP. This literature review evaluated the efficiency of two apical preparation techniques: foraminal enlargement and apical stop with maintenance of foraminal patency. **Material and methods:** A literature search was conducted in PubMed, Medline, BBO, Lilacs and Scielo using the following terms: *root canal, apical foramen, endodontics, patency file, apical size, master apical file, biomechanical preparation, foraminal enlargement, working length, dental anatomy, endodontic treatment, foraminal patency, root canal preparation, and apical stop*. All terms were combined using the Boolean operators AND/OR. After the abstracts were analyzed, 65 full texts were selected and included in this review. **Results:** The enlargement of the apical third, with or without foraminal enlargement, seems to improve endodontic treatment prognosis due to the reduction of infectious contents throughout the RCS. Foraminal patency is essential for adequateCMP when the apical stop technique is performed. **Conclusion:** Apical preparations with a greater diameter have more predictable results, and foraminal enlargement ensures better debridement and disinfection of the RCS.

Keywords: Endodontics. Root Canal Obturation. Tooth Apex.

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Introduction

The importance of microorganisms as etiologic agents of the establishment, development and perpetuation of pulp and periapical changes has been widely described in the literature.[1] The microbiota of the caries lesion or saliva is responsible for the contamination and necrosis of the pulp.[2] With the proliferation of the pulp infection, the products and by-products of these microorganisms, at first restricted to the root canal lumen, reach all the root canal system (RCS) and may access the dentinal tubules,[3] the lateral, secondary and accessory canals, the apical delta, the apical foramen and the surface of the apical root cementum.[4] As the periapical tissues are closely associated, they are also affected, promoting an antigen/antibody response that will result in severe tissue destruction, known as apical periodontitis.[5]

The success of endodontic treatments is directly associated with the reduction of both planktonic and sessile microorganisms in the RCS. This reduction should reach levels compatible with periradicular healing. Therefore, the chemomechanical preparation (CMP) is an essential treatment step.[6] The purpose of CMP is to clean and shape all the root canal using endodontic instruments, auxiliary chemical substances and irrigation/aspiration to establish an environment favorable for healing.[7]

Because of its anatomic complexity,[8] the apical third, an essential area[9] for successful CMPof the RCS, is the most difficult region to access. The crown down technique favors the movement of endodontic instruments toward the apex. It begins with the preflaring of the coronal and middle thirds and, after that, the determination of working length (WL) and apical patency.[10] Tan and Messer[11,12] and Pécora et al[13] claim that preflaring before determining apical diameter ensures greater precision in the establishment of the diameter in this region and in the definition of the anatomic diameter at WL.

The question of up to what point the root canal should be shaped is as important as controversial, and remains one of the most discussed topics in Endodontics. Several authors believe that instrumentation should be limited to the dentinal canal, 1 to 2 mm short of the radiographic apex, to preserve the pulp stump when the pulp is vital, avoiding damage to apical and periapical tissues[14]. When the pulp is necrotic, however, the apical patency is the only procedure recommended, with the introduction of a small diameter file into the root canal up to the apical foramen or 1 mm beyond it to avoid canal blockage by debris generated during instrumentation.[15,16,17] Shaping and obturation up to this limit seem to improve histologic conditions for healing.[18] According to Hargreaves and Cohen,[19] all the canal extension that is not instrumented may lodge a significant amount of microorganisms. In addition, in the apical third of the root canals with periapical lesions, infection extends to the cemental canal, where there is a predominance of strict anaerobes.[20] In this case, the purpose of cleaning and enlargement of the apical foramen is to eliminate bacteria from the apical region and, consequently, improve the predictability of endodontic treatment. Efficient cleaning of the apical third of the root canal is achieved by means of accurate determination of WL and enlargement of this region.[21]

The persistence of periradicular inflammation is directly associated with the presence of microorganisms in the apical region[22]. Instrumentation in this region, until a diameter compatible with a file #30 , should ensure the penetration of irrigants into the apical third[23]. Greater enlargements seem to be more effective in reducing the microbial load in the apical third[24]; however, the complete elimination of these microorganisms is never possible, regardless of the technique used.[11]

This study reviewed the literature about the efficiency of two techniques for apical disinfection of the RCS: foraminal enlargement and apical stop with foraminal patency.

MATERIAL AND METHODS

Literature Review

This literature review focused on two techniques of apical preparation: the foraminal enlargement and the apical stop with of foraminal patency.

A search was conducted in the Medline, Pubmed, BBO, Lilacs and Scielo databases using the following keywords for the selection of studies: root canal, apical foramen, endodontics, patency file, apical size, master apical file, biomechanical preparation, foraminal enlargement, working length, dental anatomy, endodontic treatment, foraminal patency, root canal preparation and apical stop. Each of these terms was combined using the Boolean operators AND/OR.

Initially, 79 studies were selected. After all abstracts were read, 14 were excluded, and the study sample was, therefore, composed of 65 studies published from March 1979 to July 2017. Only those publications of studies in vivo or in vitro that were very closely associated with the purpose of this study were included in the review.

Influence of apical preparation technique on canal shaping

Fornari et al.[25] conducted a histological analysis and demonstrated that in rotary canals instrumented with a rotary system using apical diameters of 30/0.02 and 35/0.04, there was a higher number of uninstrumented walls, as well as a large amount of debris. In turn, the specimens for which larger file diameters were used (40/0.02 and 45/0.02) had a greater number of walls debrided and a reduction of the amount of remaining debris. In agreement with that study, Elayouti et al[26] conducted a study using micro-computed tomography to examine instrumented canals. They confirmed that files with a greater apical diameter might achieve a more complete preparation of this region. However, both studies reached the conclusion that not even large diameters can achieve complete apical preparation of the root canals.

Borges et al[27] used histological and morphometric analyses of teeth instrumented with a rotary system using files with different diameters and found that the greater the apical diameter, the higher the number of uninstrumented walls in this region. Consequently, there was greater apical debris extrusion. The analyses made by De Deus et al[28,29] showed divergent results, as they demonstrated that the increase in the master apical file diameter did not have a positive effect on the shaping ability of the instruments, although it generated a significant reduction in the production of dentine debris.

Following the same line of investigation, Lorencetti et al[30] used scanning electron microscopy (SEM) to analyze canals instrumented with files of different apical diameters. They found that canals with greater apical diameters had smaller amounts of debris and a greater reduction of smear layer. In contrast to their findings, Tabrizizadeh et al[31] reported that a greater amount of smear layer was generated when the apical diameter was greater, even when a chelating solution (17% EDTA) was used during CMP.

Sant'Anna Jr. et al[32] evaluated the effects of the enlargement of the apical third in curved mesial canals of mandibular molars. Using micro-computed tomography analyses before and after CMP at different diameters, they found evidence that the increase in apical diameter resulted in a better root canal preparation without any significant reduction in wall thickness. In agreement with the findings by Sant'Anna Jr et al[32] and Aklaghi et al[33] confirmed that apical enlargement ensures better root canal debridement, but called attention to the need to keep an adequate thickness of the dentine walls in curved canals to avoid accidents, such as canal transportation. According to the results of their study, the authors suggested that a file #30/06 might ensure acceptable debridement in these cases.

Following another line of investigation, Gomes-Filho et al[34] examined irrigant penetration, which is another event associated with the enlargement of the apical third. They analyzed the presence or absence of over-instrumentation and found that apical infiltration, although present in all study groups, was more frequent in those in which there was over-instrumentation.

The use of small caliber instruments during the stage of apical patency does not affect the cleaning of the apical foramen, as demonstrated by the study conducted by Fonseca et al.[16] Using SEM, the authors found that small caliber instruments, or even those with diameters larger than the foramen diameter and that produced enlargement during this stage, did not touch all foraminal walls. They concluded that apical patency might only disrupt the apical biofilm, and its use is justified to keep the foramen free of obstructions and make it easier for irrigants to reach this third. In this context, Vera et al.[17] conducted an in vivo study and confirmed that the maintenance of apical patency during CMP of root canals contributed to improving irrigation in this region, and the use of passive ultrasonic irrigation (PUI) increased this effect.

Srikhant et al[35] conducted an in vitro study to determine the minimal apical enlargement for the penetration of irrigants in the apical third. They used SEM to examine canals prepared at different apical diameters and found evidence that the use of instruments #30 or with a larger diameter led to a signifi-

cant reduction of debris and smear layer, reaching up to 90%. The authors associated this finding with the mechanical action of the instrument and the use of chelators, such as 17% EDTA, and concluded that apical enlargement to a file size #30 is sufficient for the penetration of irrigating solutions into this region.

Influence of the apical preparation technique on the reduction of microbial load

Microorganisms play an important role in the development of periapical lesions, and their permanence in the apical region of the RCS in teeth already obturated is one of the causes of endodontic treatment failure. Therefore, the microbial load should be undoubtedly reduced during CMP of the root canals.

An in vivo study conducted by Yared and BouDagher[36] evaluated the influence of apical enlargement and calcium hydroxide intracanal medication (ICM) on bacterial infection of root canals. Their results suggested that microbial reduction achieved with a file #25 is as efficient as that with a file #40. The use of calcium hydroxide ICM was efficient in the elimination of bacteria regardless of the file diameter. However, in another in vivo study, Card et al[37] found different outcomes in the evaluation of bacterial samples collected in root canals after the first and second instrumentation. In their study, the apical third was enlarged using files of greater diameters, and they found that the enlargement of the apical third resulted in an increase in the percentage of bacterial reduction.

In an in vitro analysis, Coldero et al[38] compared intracanal bacterial reduction in canals treated with and without apical enlargement of the lingual roots of molars. After CMP using rotary instruments, the bacterial load reduction in each group was not significantly different. Moreover, Aklaghi et al[39] evaluated the effect of the master apical file diameter and taper on bacterial removal from the apical third. They used six different apical diameters for the preparation of extracted mandibular molars that were contaminated with E. faecalis. SEM analysis showed that all the groups had a bacterial reduction and that the increase in diameter, taper, or both did not increase the amount of reduction; as in the study by Yared and BouDagher,[36] they suggested that an instrument with a diameter #25 has the same efficacy as an instrument with a larger caliber in the removal of bacteria. Moshari et al[40] conducted a similar study, in which bacterial samples were collected from the root canals after instrumentation with files of different diameters. Results revealed that the greater bacterial reduction was achieved in the groups with the larger diameters and tapers, but there were no significant differences between the groups with the same diameter and different tapers, nor when the same taper was used with different diameters. The authors concluded that increases in diameter and taper of the master apical file do not result in significant reductions of the bacteria remaining in the root canals, and that the file #25 is sufficient for an adequate removal and preservation of the root structure.

In contrast, Mickel et al[7] found that the apical diameter affects intracanal bacterial reduction. Using SEM, they counted bacteria in the different groups in which apical preparation was performed using instruments of different diameters and found that there was a gradual reduction as the diameter of the master apical file increased, which confirmed that this technique contributes to the reduction of the bacterial load. In a similar investigation, Rodrigues et al[41] evaluated the effect of apical preparation diameter on the reduction of the microbial load. They conducted a bacterial quantification before and after rotary instrumentation using the sequence #25.08, #35.06 and #50.04 for single-rooted teeth, and #20.04, #25.06 and #35.04 for molars. Results showed that all instruments reduced the bacterial load significantly, but this reduction was significantly greater in those cases that were prepared using larger diameters.

Aware of the importance of reducing both microbial load and bacterial byproducts, Marinho et al[42] evaluated the reduction of the virulence factor found on the cell envelope of Gram-negative bacteria after the CMP of root canals with rotary instruments of different diameters (25/.06, 30/.05, 35/.04 and 40/.04). The level of endotoxins decreased with the increase of the apical diameter of the canals; however, no instrument was able to eliminate all endotoxins. Silva et al[43] conducted an in vivo study and found evidence that support these results. In patients that need endodontic retreatment, the authors compared the capacity of wider apical preparations and the use of self-adjusting files (SAF) in the reduction of en-

dotoxins. Endotoxin samples were collected after the removal of the obturation and after instrumentation with files R25, R40 and SAF. Their results showed that the file #25 promoted efficient reduction, but a significant increase was found after the use of file #40; in contrast, the use of SAF did not result in greater reduction that that seen for the R40 file.

In contrast, findings of a systematic review conducted by Aminoshariae et al[44] differ from these conclusions. The studies included in their review were selected after a rigorous analysis and were divided into those in which apical enlargement was associated with bacteria reduction[45,46,47,48] and those that supported the view that this procedure had no significant effect on the reduction of bacterial load. After analyzing several variables in the studies, the authors pointed out that the use of apical enlargement techniques during CMP did not affect bacterial reduction or elimination, regardless of the diameter used.

Influence of the technique of apical preparation on root canal transport

After the introduction of several instrumentation systems in endodontics, the maximum preservation of the original canal shape after CMP is a constant concern. Amaral et al[50] used micro-computed tomography of the mandibular molars to evaluated the centralization and apical transportation in specimens with and without previous enlargement of the cervical and apical thirds. After scanning, before and after CMP of the mesial roots, they found a decrease in the occurrence of canal transportation in the middle third of teeth in which the cervical and apical thirds had been previously enlarged, which is evidence of a more centralized preparation.

Influence of the technique of apical preparation on the development of root cracks

Another undesired event during CMP of root canals is the development of root cracks. Liu et al[51] compared the development of cracks and dentinal detachments in the apical third at different WLs after instrumentation with manual and rotary files. Their results showed that the instrument, the diameter and the WL had an effect of the development of these defects. A greater incidence of cracks was found after rotary instrumentation; teeth in which the preparation stopped short of the foramen had fewer cracks than those in which CMP stopped at or beyond the foramen. In disagreement with these results is the evidence found by De Deus et al.[52,53,54] They obtained micro-computed tomography scans before and after instrumentation of mandibular molars using different systems (reciprocating and rotary) and found that these irregularities seen after canal preparation were already present before CMP. Prado et al[55] conducted tests of resistance to fracture in premolars, in which CMP was performed with a rotary system using different diameters and at different WL. Their results showed that before obturation, the teeth in which WL was short of the foramen and prepared at smaller diameters were more resistant than those with a WL beyond the foramen and larger apical enlargements. However, when obturation was the comparative factor, the specimens with larger apical diameters and instrumentation up to the apical foramen had a similar resistance to fracture to those of intact untreated teeth.

Influence of the technique of apical preparation on postoperative pain

Silva et al[56] conducted a prospective random controlled clinical trial to compare postoperative pain between the techniques of foramen enlargement and preparation of the apical stop. After careful selection, the patients were divided into two groups: with and without foramen enlargement. After treatment, results revealed that there were no significant differences between postoperative pain reported by patients in both groups.

In a similar study, Yaylali et al[57] found results that differed from those reported by Silva et al[56] in the comparison of the two techniques. After the treatment was completed, postoperative pain was measured using a visual analog scale, and results showed that the intensity of pain in the first two days in the group with foramen enlargement was greater. After this time, there were no differences between groups, but the authors report that the highest pain scores were found when the canal was instrumented up to the apical constriction.

In a study to determine the association of apical patency with postoperative pain, Arias et al.[15] evaluated 300 patients divided into two groups: one, in which

apical patency was preserved during canal preparation, and the other without apical patency. Results showed that apical patency did not increase the occurrence, intensity or duration of postoperative pain.

Influence of the technique of apical preparation on periapical healing

Periapical healing is the major outcome expected after endodontic treatment of teeth with periapical lesions. The analysis of the possible influence of master apical file diameter on the healing of periapical tissues revealed that several studies reached different conclusions.

The pioneering study by Souza Filho et al.[58] evaluated the effect of apical enlargement on the establishment of a healing process in the teeth of dogs. The root canals were instrumented to a WL 2 mm beyond the foramen using a file #60, and the teeth were obturated 2 to 3 mm short of the apex. Histological examination of specimens revealed that there was a connective tissue growth and frequent cementum deposition upon this tissue. Therefore, the authors concluded that foramen enlargement with files #60 or larger affected periapical healing positively. Saini et al.[59] partially agreed with that result, but evaluated the association between apical enlargement and periapical healing in a study with patients randomly divided into 5 groups according to master apical filediameters, which were 2, 3, 4, 5 and 6 times greater than the diameter of the first apical biding file. After clinical and radiographic follow-up, the authors found that the percentage of healing increased when diameters 3 times greater than that of the first apical biding file were used.

As support for the claim that greater apical diameters produce better periapical tissue healing, our search yielded a systematic review conducted by Aminosharіae et al.[60]. After careful selection and analysis of all variables in various studies, separating those in which a greater apical diameter contributed for better healing[59] from those that found no significant differences for the association of these two factors[61,62,63], the authors concluded that the best clinical evidence suggested that, in teeth with pulp necrosis and persistent periapical lesions, a greater enlargement of the apical third offers better chances of healing.

In contrast, Souza et al.[63] found that healing might not have a direct association with this technique. After a comparison of initial and follow-up radiographs of two different groups of patients, one in which root canals were instrumented using three files (first apical biding file + 2 diameters larger) and one with 4 files (first apical biding file + 3 diameters larger), the authors found that complete healing was very similar between groups and concluded that enlargement did not affect treatment outcome. Azim et al.[64] listed criteria that confirmed these findings after following up patients that had received endodontic treatment. In their study, several factors were included, such as master apical file diameter, and they analyzed two variables: factors that affected treatment success and those that affected healing time. They found that the master apical file diameter did not affect treatment outcome, but endodontic treatments that used master apical files with diameters smaller than a size #35 had longer healing times.

Discussion

The complete elimination of microorganisms from the RCS is an objective that has been pursued for a long time, but which has never been achieved. Different CMP techniques have been developed in an attempt to define protocols to attain this goal. The foramen enlargement technique was created as an option to the traditional apical stop technique because of the complexity of the RCS, particularly the apical third, and of the possible reduction of infectious contents, that is, microbial load and microbial byproducts. In the more recent technique, the apical third may be enlarged with or without foramen enlargement, whereas the apical stop technique only maintains apical patency.

The basis of the apical enlargement technique is the idea that adequate cleaning is achieved by increasing the apical third enlargement and, thus, making it cleaner, although using a WL that does not change the morphology of the apical foramen and that does not reach periradicular tissues.[25,27-30,32,33,35] In contrast, foramen enlargement requires that cleaning and enlargement of the apical region involve the apical foramen. To achieve foraminal cleaning, instrumentation beyond the apical foramen may be required to ensure that all the contaminated walls are mechanically debrided by endodontic files.

Apical instrumentation usually results in the formation of an apical stop. Both the foramen enlargement and the apical stop techniques aim at establishing and maintaining root canal patency. Apical patency maintenance follows mechanical and biological principles of the action of small caliber instruments used in all the extension of a root canal.[15,16,17] Scientific evidence, as presented in this literature review, should guide the decisions about endodontic treatments, as differences may give rise to numerous questions and discussions about ideal WL and enlargement to achieve greater predictability.

Some authors claim that, in CMP of the RCS, larger apical third diameters may promote better shaping, because their findings suggest that the greater the instrument diameter, the more internal walls will be debrided,[5,27,29,30,32,33] regardless of type of instrumentation, which may be manual, rotary or reciprocating. Apical instrumentation also facilitates the removal of debris and smear layer, which constitute a "pathogenic cocktail" for periapical tissues.[30,33] In contrast, Tabrizizadeh et al.[31] disagree with those conclusions and suggest that instrumentation with greater diameters results in more smear layer, which does not contributed to canal cleaning.

The idea that maintaining apical patency during CMP ensures foramen cleaning is a hypothesis. The instruments used for this procedure do not adapt to the foraminal walls, not even when larger diameters are used,[16] which justifies enlarged preparations of the apical third.

However, various authors have described some unwanted outcomes associated with diameter enlargement in the apical third: greater amount of extruded material into the periapical region,[27] apical infiltration,[34] apical transportation,[33] weakened canal walls[26] and root cracks and fractures.[51,55] Other studies showed that unwanted effects, such as unnecessary dentine removal from the canal walls and a high production of dentin debris, do not occur in this type of enlargement,[32,29,52] which improves centralization and reduces canal transportation.[50] Apical enlargement does not seem to affect the formation of root canal micro-cracks directly. Examinations using conservative techniques, such as micro-computed tomography, reveal the same dentinal defects seen before CMP, which confirms that they should not be associated with the preparation technique used.[52,53,54] The same is true of the association with root fractures. Prado et al[55] found that resistance to fracture increases in a similar pattern after canal obturation, regardless of WL or the master apical file.

Infection in the RCS may persist because of numerous factors, such as microorganism resistance, chemical irrigants used, apical anatomy, which often blocks the mechanical action of instruments, access of irrigants to areas that are difficult to reach, and biofilm, which is the microbiota organized in structures protected by complex external matrices that hinder their disorganization and elimination.[65]

Some studies point out that these barriers may be minimized by larger apical preparations, by maintaining apical patency, or by preparations with a WL up to a point beyond the foramen.[42] These procedures would reduce microbial load, not only because of the mechanical action of larger diameter instruments on canal walls, but also because they facilitate the delivery of irrigants to regions that are difficult to access and thus promote a more efficient desinfection.[7,37,41-43] This was evident in cases of retreatment in which the levels of endotoxins were reduced with the increase of instrument diameters during CMP.[41,43] However, other authors claim that instruments with a smaller diameter achieve the same reduction in intracanal microbiota[36,38,39,40] when an ICM is added to the treatment,[36] or when using techniques that do not include the enlargement of the apical third.[38] Still others suggest that, regardless of the amount of apical enlargement, this factor is not responsible for eliminating bacteria during treatment.[44]

One of the arguments against instrumentation beyond the apical foramen is that the mechanical action of instruments on periradicular tissues may irritate them and result in more intense postoperative pain.[57] Silva et al[56] described criteria that contradicted these findings, as postoperative pain was similar to that of patients whose foramen was not instrumented. Similarly, Arias et al.[15] did not find any association of intensity, duration or occurrence of pain with apical patency.

Periapical healing is the restoration of the health of periapical tissues with pathologies resulting from the progression of intracanal infection. This objective may be achieved even under unfavorable conditions, when CMP techniques that extend foraminal

enlargement to beyond the apical foramen are used,[58] or when this region is not submitted to mechanical preparation.[59] The analysis conducted by Souza-Filho et al[58] revealed that the use of larger diameters in the apical third during CMP to a WL that reaches the periapical tissues produced extremely favorable healing conditions. Other studies also associated preparations using larger diameters with greater chances of healing.[59,60] However, still other authors found that master apical file diameter is not directly associated with periradicular healing[63] and affects only healing time, but not treatment outcome.[64]

The evidence presented in this literature review shows that, considering mechanical and biological factors, apical third enlargement and foraminal enlargement during CMP undoubtedly have advantages over more conservative apical preparations. The decision about what WL to use for RCS instrumentation should take into consideration that endodontic treatment success is directly associated with the infectious contents inside the canals. Therefore, the foraminal enlargement technique should not restrict CMP to a predefined limit, because bacteria do not act only in the dentinal canal. Preparations that follow all the canal length ensure greater microorganism reduction and, consequently, greater chances of success. The benefits achieved by this technique are greater than its possible risks. Maintaining apical patency during all CMP process is essential; although this procedure does not clean the foramen, it prevents the accumulation of dentin debris and possible changes in canal morphology and WL, thus improving the disinfection of the apical third.

Conclusion

According to this literature review, the advantages of apical third enlargement and foramen extension for endodontic treatment predictability are evident. However, further randomized clinical trials should evaluate the success rates and side effects of CMP with foraminal enlargement in comparison with the traditional preparation up to the cementodentinal junction.

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