Effect of apical expansion in decreasing microorganisms: a literature review

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ABSTRACT

Mechanical preparation of the apical third is a major challenge in root canal treatment due to the complex anatomy of this region. The presence of biofilm in the apical foramen may be related to endodontic failures; therefore, its removal becomes indispensable. Due to anatomical variety and the presence of biofilm, foramen instrumentation may be related to the success of root canal treatment. Thus, the aim of this literature review was to determine whether the enlargement of the apical third contributes to reducing microorganisms, assisting in endodontic repair. It can be concluded that the enlarging the apical third as well as cleaning the foramen, aided by chemical solutions, contribute to the reduction of microorganisms in this region, thereby favoring the success of endodontic therapy.

Keywords: Root canal preparation. Endodontics. Biofilm.

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Introduction

One of the challenges in Endodontics is to determine the working length of endodontic instruments. The final millimeters of the apical region (3 to 4 mm) have been described as the most critical region for the treatment of infected root canals,[1] not only due to the anatomical hurdles faced when trying to reach them, but also due to the difficulty achieving adequate cleaning and antisepsis of the region. Microscopy studies reveal that the most constricted region of the root canal is approximately 0.59 mm far from the apical foramen[2] and 0.89 mm from the anatomic apex.[3] Conceptually, it is still considered that 92.5% of constrictions are located between 0.5 and 1 mm from the apex.[4,5] However, recent studies[3,6,7] reveal that, in fact, the distance from the radiographic vertex to the apical foramen can vary between 0 and 3 mm, and using clinical or radiographic analyses alone to determine insignificant values (which may vary in 0.5 mm) becomes rather impossible. Oftentimes, even though apparent success is noted by radiographic examination, absence of symptoms or of apical periodontitis in a canal that has been inappropriately disinfected, there may be remaining microorganisms, particularly in the periapical region. Therefore, preparing regions near the apical foramen of contaminated canals improves the asepsis of the root canal system, whereas establishing a limit of 0.5 to 1 mm or more short from the radiographic vertex would allow non accessed areas to remain contaminated.[8]

The aim of this literature review was to determine whether the enlargement of the apical third associated with foraminal enlargement contributes to the real reduction of bacteria inside the root canal, thereby assisting endodontic repair.

Literature review

Benatti et al[9] performed a histological study on dogs, in which 134 canals were instrumented 2 mm beyond the apical foramen. The apexes were enlarged with K-files #40, #60 or #80, and filled 1-3 mm from the apex. Overinstrumentation caused periodontal ligament and alveolar bone disruption. The authors concluded the following: 1) the pulp stump destroyed by instrumentation can be recovered by connective tissue proliferation from the periodontal ligament; 2) enlargement of root canal apical portion diameter allows connective tissue growth into the space unfilled by gutta-percha; 3) there were no significant differences in the repairing processes established in three different diameters of root canal apical thirds (with #40, #60 or #80 files); 4) presence of inflammation-free granulation tissue; over time, a gradual maturation process characterized by cellular reduction, higher fiber density and well differentiated vascular walls was established; 5) a type of cement built up on the inner wall surfaces of the apical canals and a progressive increase in thickness was observed over time; 6) bone growth also occurred, dentin and cement particles resulting from instrumentation spread to the periodontal ligament which became coated with a cementoid matrix.

Souza Filho et al[10] performed pulp exposure of 32 dog teeth in order to trigger contamination, with periapical inflammation lasting for 45 days. Root canals were overinstrumented 2 mm beyond the foramen with a K-file #60 and filled 2-3 mm short from the radiographic apex. Ninety days after root canal treatment, repair and connective tissue growth inside the root canal were observed in 67.8% of cases. These results suggest that the diameter of the foramen and the intensity of root canal contamination are determining factors for the repair of periapical tissue in pulp necrosis cases.

Baugh and Wallace[11] conducted a literature review and found that opinions differ as to whether enlarge the apical third. Some studies show the effectiveness of this procedure, while other studies claim that the procedure effectiveness is due to the use of auxiliary chemical substances. Therefore, the authors concluded that, as endodontists, we must be careful in adopting the best available evidence to support our clinical treatment plans. Ignoring science for the sake of speed and simplicity can pose risks to final treatment outcomes. Moreover, with the anatomical variability of the periapical region, we must seek techniques that aid the professional to determine the correct size of apical instrumentation.

Borlina et al[12] conducted a study on dogs, in which 40 teeth were instrumented and filled with Sealer 26 and Endomethasone. Teeth were instrumented up to a K-file #55, at the cemento-dentinal junction. In 20 root canals, cemental canal and foramen were enlarged up to K-file #25. The remaining 20 canals had the apical cement barrier preserved (without enlargement of the apical foramen). All canals received intracanal medication of calcium hydroxide for 21 days and were filled with gutta-percha and one of the two following sealers: G1) Sealer 26/apical enlargement; G2) Sealer

26/no apical enlargement; G3, Endomethasone/apical enlargement; G4, Endomethasone/no apical enlargement. After 180 days, histological analysis of these canals was performed, newly formed cementum was found, in addition to areas of cementum repair and bone resorption, presence of microorganisms, inflammatory infiltrate and periodontal ligament in good conditions. Significantly better apical repair was obtained when enlargement of the foramen was carry out and Sealer 26 was used. The authors concluded that apical foramen enlargement and the use of medication containing calcium hydroxide were most favorable for curing chronic periapical lesions.

Borges et al[13] conducted an *in vitro* study with 32 lateral incisors, 16 with curvature angles less than or equal to 10° (GI) and 16 with angles between 11° and 25° (GII), subject to rotary instrumentation with the HERO system with different diameters: A, 30.02 and B, 45.02. Material extruded through the apical foramen was collected and evaluated, with the conclusion that the cleaning effect on the apical region did not differ between groups, taking curvature and surgical diameter of instruments used for apical preparation into consideration. The amount of extruded material was greater in canals with a gentle curvature, prepared with the 45.02-diameter instrument.

Souza et al[14] evaluated 80 teeth with periapical lesion and divided them into two groups: G1, instrumented with up to three files; and G2, instrumented with up to four files, 1 mm from the apex, treated with calcium hydroxide and filled after 14 days. Two years later, 43 patients returned for follow-up, and had baseline and follow-up radiographs compared. The new radiographs showed that 22 (91.67%) out of 24 patients in G1, and 17 (89.47%) of 19 patients in G2 underwent complete repair, with no significant differences between groups. The authors concluded that enlargement of the apical third did not change the outcomes of root canal treatment of teeth with periapical lesion.

Marinho et al[15] conducted a study with 40 teeth, in which *Escherichia coli* endotoxin was inoculated into 30 canals while ten teeth served as negative control. After the incubation period, samples of endotoxin were collected from the canals before instrumentation (T_1). Instrumentation was performed with the following Mtwo™ rotary system sequence: 10/.04, 15/.05, 20/.06, 25/.06, 30/.05, 35/.04 and 40/.04. To check for the effectiveness of increasing apical enlargement in removing endotoxins, new endotoxin samples were collected from all root canals after instrumentation, with the following instruments: #25/.06 (T_2); #30/.05 (T_3); #35/.04 (T_4); and #40/.04 (T_5). The results were statistically compared and revealed that an increased level of endotoxin removal was achieved by extensive apical enlargement: T_2 (#25/.06) = 89.2%; T_3 (#30/.05) = 95.9%; T_4 (#35/.04) = 97.8%; and T_5 (#40/.04) = 98.2%. Substantial reduction in endotoxin content was obtained in T_4 and T_5; however, root canal preparation was unable to eliminate endotoxins. Therefore, it is concluded that the levels of endotoxin in the root canals can be reduced if the extension of apical enlargement is increased.

Table 1 discloses scientific studies on the preparation of the apical third and the quality of microorganisms reduction by applying different research methods.

In order to evaluate the transportation of the apical foramen when stainless steel or nickel-titanium instruments are used as patency instruments, Goldberg and Massone[16] evaluated 30 teeth divided into two groups: A, instrumented with stainless steel pre-curved K-files #10, #15, #20 and #25, using them as patency files (each instrument was used by moving 1 mm beyond the apical constriction, three times); B, K-type stainless steel instruments and nickel-titanium K-files #15, #20 and #25, applying the same procedure used for A. It was observed that the transportation of the apical foramen was detected in 18 of the 30 samples analyzed, with no statistical difference between stainless steel or nickel-titanium files. The authors concluded that the patency instrument should have the lowest file size possible.

Brito-Júnior et al[17] evaluated transportation of the apical foramen associated with ProTaper™ Universal rotary system in 20 canals with curvatures varying between 25° and 35°. Teeth were instrumented with this system and pre-enlargement was carried out with S1 and SX. A K-file #15 was inserted into the canal up to the working length, and an initial digital radiograph was taken thereafter. Instruments were used up to the working length and following the manufacturer's sequence (S1, S2, F1, F2, F3). New radiographs were taken after F1, F2 and F3 instruments were used, with each instrument inserted into the root canal. Radiographic images were superimposed and Adobe Photoshop™ software was used to measure the distance between the ends of the rotary instruments and the end of the K-file #15. The authors found that instrument size significantly

Table 1. Scientific papers selected between 1985 and 2012, related to the topic of apical preparation x reduction of microorganisms.

Author	Year	Type of study	Objective	Conclusion
Benatti et al[9]	1985	Histological in dogs	Investigate the effect of diameter enlargement of the root canal apical portion.	Enlargement of the apical portion creates conditions that allow the growth of connective tissue inside the space unfilled by gutta-percha. There was no significant difference in repair among the different sizes of apical dilation.
Souza Filho et al[10]	1987	Histological in dogs	Evaluate the influence of apical foramen enlargement over periapical repair of infected dog teeth.	Results suggest that foraminal diameter and the intensity of root canal contamination are determining factors for periapical tissue repair in cases of necrotic pulp.
Borlina et al[12]	2010	Histological in dogs	Evaluate the influence of foramen enlargement in the healing of chronic periapical lesions.	Apical foramen enlargement and the use of medication containing calcium hydroxide were most favorable for curing chronic periapical lesions.
Borges et al[13]	2011	*In vitro*	Evaluate cleanliness of the apical portion of root canals with mild or moderate curves, submitted to preparation with a rotary system, and the amount of material extruded to the periapical area.	The amount of extruded material was greater in canals with mild curvature that had been prepared with instrument 45.02 in diameter.
Souza et al[14]	2012	Clinical	Evaluate whether enlargement of the apical third of the root canal is a determining factor for the repair of periapical lesions in root canal treatment.	Enlargement of the apical third did not change the outcomes of endodontic treatment of teeth with periapical lesion.
Marinho et al[15]	2012	*Ex vivo*	Investigate the influence of apical enlargement magnitude in reducing the level of endotoxin in the root canals, using rotary instruments.	Endotoxin levels of root canals can be reduced if we increase the magnitude of apical enlargement.

affects apical transportation. Instrument F3 showed the highest apical transportation, when compared to F1 and F2, while between these last two there was no difference. The authors concluded that apical transportation in curved canals was lower when apical preparation files of smaller diameter were used.

In a study by Silva et al,[18] 30 roots were analyzed. Preparations were performed with hand stainless steel instruments, Mtwo system, and Reciproc R25 files. The roots were divided into three groups and prepared according to the manufacturer's instrumentation systems. All groups were prepared 1 mm beyond the vertex. Data were analyzed and revealed that the group instrumented with hand files showed higher foraminal transportation when compared with Mtwo and Reciproc groups. The Reciproc group showed lower transportation when compared to the Mtwo group (10/.04, 15/.05, 20/.06 and 25/.06), with the conclusion that stainless steel instruments caused significant foraminal transportation, while the Reciproc system proved to allow safe apical preparation and little transportation.

Table 2 discloses scientific studies on the type of apical third preparation and transportation of the apical foramen.

Ferraz et al[19] studied five groups with 20 extracted teeth and single canals. To this end, they used the manual hybrid instrumentation technique, and three techniques with nickel-titanium rotary systems (Profile .04, Quantec 2000 and Pow-R). After instrumentation, the irrigating solution volume and the weight of extruded debris were determined, and the authors noted that with the mechanical techniques, extrusion of debris was decreased in comparison to the manual techniques, with no statistical difference between the force used with the manual technique and the engine-driven methods. The volume of irrigating solution extruded through the apex was directly associated with the weight of the extruded material; the hybrid technique was associated with greater extrusion of both debris and irrigant. Therefore, the study concluded that, in general, nickel-titanium engine-driven systems cause less apical extrusion.

Table 2. Scientific papers selected between 2002 and 2014, related to the topic of apical preparation x apical transportation.

Author	Year	Type of study	Objective	Conclusion
Goldberg and Massone[16]	2002	*In vitro*	Evaluate the transportation produced in the apical foramen when stainless steel or nickel-titanium instruments #10, #15, #20, #25 were used as patency instruments.	If a patency instrument is used, it should be the smallest instrument possible.
Brito-Júnior et al[17]	2013	Clinical	Evaluate apical transportation associated with ProTaper™ Universal rotary system F1, F2 and F3 in curved canals.	Decreased apical transportation was produced when F3 rotary file had not been used.
Silva et al[18]	2014	*Ex vivo*	Evaluate transportation of the foramen during foraminal enlargement after manual instrumentation with stainless steel Flexofile files (50, 45, 35,30 and 25), and with Mtwo preparation system (10/.04, 15/.05, 20/.06 and 25/.06) and Reciproc R25 files.	The Reciproc system showed safe apical preparation with little transportation.

Adl et al[20] compared different techniques applied to three groups, each group with 12 mesiobuccal roots of first maxillary molars: G1, hand K-files; G2, FlexMaster system; G3, Mtwo system. The debris expelled from the foramen were collected and analyzed; the authors observed that the group subjected to the manual technique had the highest mean debris weight when compared to the other two groups. G3 had the lowest mean value, although it was not significantly different from G2. The authors concluded that the rotary techniques cause less apical debris extrusion.

Deonizio et al[21] evaluated 40 mandibular incisors, according to the performance or nonperformance of apical patency during root canal preparation with manual and ProTaper techniques. After removing cement from the root canals, each specimen was cleaned in its foraminal portion, with #15, #20 and #25 instruments. The extruded material was collected by filters that were weighted before and after collection. Differences were estimated, and no significant difference was found among groups or subgroups. The ProTaper system allowed less material to be extruded, regardless of the presence or absence of apical patency, followed by the manual technique without and with apical patency. Additional amounts were collected while cleaning the foramen, regardless of the instrument used, presence or absence of patency or the technique used for removal of cement. The authors concluded that apical patency did not influence the amount of extruded material when the rotary system used was ProTaper.

Sowmya et al[22] evaluated 60 teeth divided into four groups, in which root canal preparation was carried out by means of the step-back technique with manual instrumentation with K-files; the crown-down technique with ProTaper and K3 systems; and the hybrid technique with LightSpeed LSX . Teeth were subjected to histological processing and analyzed; results revealed that manual instrumentation with K-files showed the highest amount of apical extrusion of debris compared to ProTaper, K3 and LightSpeed LSX. Results also showed that there was no statistical difference among groups, particularly regarding the presence of intracanal debris in the apical third. The authors concluded that all instrumentation techniques allow debris extrusion, but the NiTi engine-driven systems expelled less apical debris than manual instrumentation.

In a study by Tanomaru-Filho et al,[23] 12 mandibular incisors were instrumented and, after foraminal enlargement with different diameters (#40 and #60), the root canals were filled with radiopaque solution thickened with propylene glycol and zinc oxide. Two types of irrigation 27G needles were used, with different designs (apical or side opening), with two streams corresponding to 15 or 25 mL/min, and penetration of the needles in two depths (3 and 6 mm short from the apex). Before and after irrigation, the teeth were X-rayed by means of a digital radiographic system. Analysis showed no statistical difference in terms of foraminal diameter, type and depth of needle penetration, irrigation flow in cleaning parameters (above 97%) and apical extrusion (not greater than 0.38 mm^2). The authors concluded that all irrigation protocols evaluated provided cleaning of the root canal and low apical extrusion of the irrigating solution.

Table 3 discloses the scientific studies on preparation of the apical third, with extrusion of debris contaminated by the apical foramen.

Gurgel-Filho et al[24] evaluated 40 teeth which were divided into two groups: G1 (experimental), foraminal enlargement up to #30 file and working length of 1-2 mm short from the foramen; G2 (control), working length of 1-2 mm short from the apex and maintenance of pulp stumps. Vitality was analyzed based on clinical and radiographic aspects. All teeth were treated within a single session and ZX™ Root apex locator was used to determine the working length, along with radiographic evidence. Pain was evaluated for a period of 24 and 48 hours. The authors found no statistical difference between the two groups, concluding that apical foramen enlargement did not increase the incidence of pain.

Gambarini et al[25] conducted a study with 90 patients divided into three groups with premolars and molars instrumented within a single session: G1, crown-down technique using TF instruments; G2, Waveone 25/.08 single instrument technique; G3, TF Adaptive sequence of three files. Evaluation of postoperative pain was performed after three days by means of a visual analogue scale in which difference between Waveone technique and the other two techniques was observed. There were no significant differences between TF and TF Adaptive, and, when evaluating severe pain, the incidence of symptoms was greater with the Waveone technique. The authors concluded that the difference in postoperative pain can be related to the different instrumentation techniques.

Table 4 discloses the selected scientific papers associating preparation of the apical third with symptoms after root canal treatment.

Discussion

Determining the ideal working length in endodontic instrumentation, carrying it out 1 mm short, at the foramen limit or enlarging it, is still a divergent matter in the literature. It is known that chemical-mechanical preparation is responsible for the decontamination and removal of microorganisms that infect the root canal system. Being aware of that as well as of the great anatomical variability that exists in the apical third of root canals, cleaning the last millimeters of root canals becomes largely responsible for the success of root canal treatment.

Chemical-mechanical preparation of the apical third, with involvement of the cemental canal (apical enlargement), has been proven in the literature not to interfere in the repairing process of the region, provided that removal of microorganisms is performed.[9,10,12] Apical enlargement

Table 3. Scientific papers selected between 2001 and 2014, related to the topic of apical preparation x debris extrusion.

Author	Year	Type of study	Objective	Conclusion
Ferraz et al[19]	2001	*Ex vivo*	Check the amount of debris and irrigating solution in apical extrusion after instrumentation.	Nickel-titanium rotary systems cause less apical extrusion.
Adl et al[20]	2009	*In vitro*	Compare the amount of debris expelled from the foramen during root canal preparation, with the hand and rotary techniques.	Engine-driven techniques cause less apical extrusion of debris.
Deonizio et al[21]	2013	*Ex vivo*	Investigate the effect of apical patency on the amount of extruded material.	Apical patency does not influence the amount of extruded material when the ProTaper system is used.
Sowmya et al[22]	2014	Histological	Evaluate the amount of apical extrusion of debris during manual technique and three different types of rotary techniques.	NiTi systems expelled less debris than the manual technique.
Tanomaru-Filho et al[23]	2014	*Ex vivo*	Evaluate the influence of foraminal diameter, and penetration and needle type, and irrigation flow of cleaning and apical extrusion.	All irrigation protocols evaluated provided cleaning and little apical extrusion.

Table 4. Scientific papers selected between 2010 and 2013, related to the topic of apical preparation x postoperative pain.

Author	Year	Type of study	Objective	Conclusion
Gurgel-Filho[24]	2010	*In vivo*	Check postoperative pain in teeth subject or not to foraminal enlargement.	Apical foramen enlargement did not increase the incidence of pain.
Gambarini et al[25]	2013	*In vivo*	Evaluate and compare postoperative pain, using three different instrumentation techniques.	Difference in pain sensitivity may be related to different instrumentation techniques.

not only contributes to reducing microorganisms, which are generally organized in the form of biofilm on the walls of the root canal, but also aids in the removal of by-products, such as endotoxins, which are responsible for the formation of periapical lesions and, in some cases, are involved with post-treatment symptoms.[15]

However, apical enlargement should be performed with caution, given the anatomy of each case. The literature shows that apical transportation is a major concern in mechanical instrumentation due to the different conical shape of instruments. Nevertheless, previous studies reveal that, when compared to manual instruments, there was no statistical difference in apical foramen transportation.[16,17] Apical enlargement is thus necessary to better decontamination of the apical third and can be carried out with rotary and nickel-titanium reciprocating instruments without any concern over apical transportation when the anatomy of the region is respected.[18]

Sensitivity or even painful symptoms after chemical-mechanical preparation can be attributed to contaminated debris extrusion, or not, to the periapical region. Enlargement of the apical third with nickel-titanium instruments, in spite of instruments being similar in diameter, does not cause greater extrusion of debris to the periapical region.[19,20,22] Removal of smear layer formed after chemical-mechanical preparation, both in manual and mechanical instrumentation, does not raise major concerns, since, with proper enlargement of the cervical, medium and apical thirds and the use of needles with ideal gauge for irrigation, thus allowing insertion near foramen, it allows effective irrigation and removal of debris, thereby decreasing extrusion.[23]

The trauma of foramen overinstrumentation, causing disorganization of periapical tissues, does not lead to postoperative sensitivity, regardless of pulp tissue vitality, thus demonstrating that the chemical-mechanical preparation procedure may involve the cemental canal without postinstrumentation consequences to the patient.[24,25]

Conclusion

Based on this literature review, we conclude that proper preparation of the apical third, respecting the anatomical variations of the region, contributes to better mechanical removal of biofilm and improves the action of auxiliary chemical substances in this region, thus contributing to the success of root canal treatment and periapical repair.

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