ECRONICON OPEN ACCESS
EC DENTAL SCIENCE
Review Article

Apical Extrusion in Endodontics- A Literature Review of an Intrinsic Occurrence during Root Canal Treatment

Disha Baxi[1]*, Preeti Doddwad[2] and Shavina Patil[3]

[1]Department of Conservative Dentistry and Endodontics, KAHER V.K Institute of Dental Sciences, Belagavi, Karnataka, India

[2]Professor, Head of Department, Department of Conservative Dentistry and Endodontics, KAHER V.K Institute of Dental Sciences, Belagavi, Karnataka, India

[3]Reader, Department of Conservative Dentistry and Endodontics, KAHER V.K Institute of Dental Sciences, Belagavi, Karnataka, India

***Corresponding Author:** Disha Baxi, Department of Conservative Dentistry and Endodontics, KAHER V.K Institute of Dental Sciences, Belagavi, Karnataka, India.

Received: September 06, 2022; **Published:** October 27, 2022

Abstract

Despite strict length control of the endodontic instruments during root canal preparation, various dentinal remnants, tissue fragments, microorganisms, and the intracanal irrigant may be extruded from the apical foramen into the periradicular region. One of the foremost vital complications related to or that happens as a consequence of apical extrusion throughout the root canal procedures is interappointment flare-ups and postoperative pain that is undesirable for each patient and the practitioner. There has been a fast evolution of root canal instruments and irrigation systems through the last decade, and plenty are assessed for their debris extrusion potential. The purpose of this review was to identify publications regarding the evaluation of debris, bacteria, irrigant, and the obturating material extrusion during root canal treatment. The content of the review was limited to apical extrusion of debris, irrigants, bacterial extrusion, obturating material, and medicament placement. The review provides an update on the present standing status of apical extrusion in endodontics.

Keywords: *Apical Extrusion; Debris; Endodontic Treatment; Reciprocation; Rotary; Irrigation; Obturation; Medicament*

Introduction

One of the goals of root canal obturation in endodontics is the three-dimensional obliteration of the root canal system to achieve a fluid-tight seal to ensure successful treatment [1]. Chemomechanical preparation of the root canal system is a major pre-requisites of contemporary root canal treatment [3]. Complete preparation of the root canal space is one in all the most vital stages in root canal preparation [1].

Despite strict length control of the endodontic instruments during root canal preparation, various dentinal remnants, tissue fragments, microorganisms and the intracanal irrigant may be extruded from the apical foramen into the periradicular region [1].

The extruded material referred to as the 'worm of necrotic debris' has been related to periapical inflammation and postoperative flare-ups [2].

It is noteworthy to mention that the concept of apical extrusion should not only be restricted to debris or liquid forced into periapical tissues during mechanical instrumentation. There are also other types of apical irritations during root canal treatment that may disrupt the integrity of periapical structures, such as extrusion of filling materials, intracanal medicaments or root canal instruments. Extrusion of intracanal material may be in the form of filling materials, necrotic pulp tissue, bacteria, or irrigants. In general, extrusion of cleaning, medication or filling materials beyond the apical terminus into the encompassing tissues might lead to delayed healing or perhaps the treatment failure because of a foreign body reaction [2].

One of the foremost vital complications related to or that happens as a consequence of apical extrusion throughout the root canal procedures is interappointment flare-ups and postoperative pain that is undesirable for each patient and the practitioner. Siqueira has drawn attention to the fact that some type of balance exists between microbial aggression and host defense in asymptomatic chronic periradicular lesions. In case microorganisms are extruded apically throughout chemomechanical preparation, the balance will be discontinuous with the periradicular tissues being challenged by a lot more irritants. An acute reaction can result to re-establish the balance [2].

Chapman., *et al*. [4] was the primary to verify the expulsion of infective material from the root canal system during instrumentation. Following the study by Van de Visse and Brilliant [5] who reported the significance of irrigation in apical extrusion, several authors attempted to evaluate the extrusion levels of different manual preparation techniques as well as sonic and ultrasonic systems [2].

The general opinion of most authors is that apical extrusion is inevitable during root canal instrumentation, and no methodology has yet been developed to completely avoid this phenomenon. In this article, we briefly review the relevance of apical extrusion in endodontic therapy from a clinical and biological perspective.

Why is apical extrusion a concern during endodontic treatment?

The extrusion of cellular debris into the periradicular tissues during chemomechanical preparation can cause postoperative pain [7]. In asymptomatic periradicular lesions associated with infected teeth, there is a balance between the microbiota and the host. As debris and microbes are pushed into the periradicular tissues during biomechanical preparation, the host is exposed to more irritants than before. As debris is pushed beyond the apical foramen, it increases the influx of exudates and blood into the root canal, increasing the food supply to bacteria and exacerbating chronic lesions. The result is a temporary imbalance between attack and defense, and an acute inflammatory response to restore the balance. Siqueira documented that the strength of the inflammatory response depends on the number and virulence of the microorganisms extruded from the root canal [6].

Although the amount of debris and irrigants pushed out can be controlled by the operator up to some extent whereas the microorganisms which are extruded are a factor that is very difficult to control. When infectious clonal species of pathogenic bacterial species are present within the root canal system and are propelled into the periradicular tissues during over instrumentation, even small amounts of infected debris can cause or exacerbate periradicular inflammation [8].

Factors influencing apical extrusion

The influence of disruption of apical constriction on periapical extrusion

Biomechanical preparation is an integral part of root canal therapy. This includes mechanical cleansing by instruments and the use of irrigants. Over the past 40 yrs several studies have verified that debris is certainly forced out during root canal preparation and that some instrumentation techniques may extrude less material than others [3].

In clinical practice, there may be instances where proper apical constriction lacks; it may not have formed in immature teeth or it may be resorbed due to long-standing periapical lesion. Besides, the apical constriction may be disrupted iatrogenically (e.g. because of incorrect working length determination) or intentionally by the operator (e.g. to enable the discharge of periapical abscess through the root canal). It is appropriate to stop the shaping at the level where pulp tissue ends, leaving a cement cone to allow a cemental repair after the endodontic treatment. Therefore, the apical constriction (or CDJ) appears to be an ideal apical limit to be used as a matrix to support the closing material and avoid any overfilling [8].

There is an increase in the amount of the apically extruded material corresponding to an increase in the diameter of the apical patency.

Influence of a glide path on apical extrusion of debris during canal preparation

It is well known that the creation of a glide path in the canal enhances the performance of NiTi instruments [9]. However, the manufacturers of single-file NiTi systems recommend that the clinical procedure of these systems do not consider the preliminary creation of a glide path prior their use in canal preparation. Zanette., *et al*. [10] reports that glide path preparation allows the preservation of a pathway throughout the WL, thus avoiding excessive binding in the canal. In addition, pre-flaring tends to reduce procedural errors such as ledge formation and apical transportation [11]. Procedural errors are more likely to occur while preparing the curved root canals. Apical transportation and irregular foramen widening can lead to poor sealing efficiency, high debris extrusion rate and postoperative discomfort [11].

Influence of canal curvature on apical extrusion

Many studies on extrusion have used single-rooted teeth with relatively straight root canals of less than 5 - 10 degrees of curvature. On the other hand, it is quite likely that the practitioner will be faced with severely curved roots in clinical practice. Leonardi., *et al*. [12] focused on roots with greater curvatures and determined no significant differences between slight and moderate curvatures, nor any difference between the evaluated techniques in terms of debris extrusion.

Influence of instrument pitch design on apical extrusion

The influence of pitch design of a specific instrument, NRT files (MANI Inc, Tochigi, Japan) was assessed by Elmsallati [13] with short, medium, and long pitch designs. The results showed that the short-pitch design extruded less debris compared to the medium and long ones.

Effects of apical extrusion on periapical area

One of the most significant complications related to or that occurs as a consequence of apical extrusion is inter-appointment flare-ups and postoperative pain that is an undesirable occurrence both for the patient and the practitioner [2]. The origin of the post-endodontic flare-up is poly-etiological; mechanical, chemical, and microbial factors influence its development [3]. Regardless of the type of the factor, the flare-up depends on the extent of the periradicular tissue damage, its severity, and the strength of the inflammatory response. These factors are interrelated and directly dependent on each other [3].

Mechanical factors

Biomechanical preparation is one of the factors causing the success of endodontic treatment. Despite the technique chosen, some of the infected debris are extruded into the periodontal tissues during the mechanical preparation of the root canal.

In the biomechanical preparation of the root canal, it is crucial to reach the physiological apex of the root, the end of the root canal-the CEJ. The mechanical irritation of periradicular tissues is mainly caused by over instrumentation of the root canal and extrusion of the filling material from the apical foramen [3].

Microbial factors

Microorganisms of the root canal system are involved in the pathogenesis of asymptomatic apical periodontitis and can invade the periradicular tissues along with virulence factors. Various types of microorganisms proliferate in the apical area of the root canal. The 5 mm apical microbial density of the apical root area may reaches a maximum of 106 bacteria and is dominated by anaerobic microorganisms [3]. Because of its intricate anatomy (accessory canals, apical deltas) and high bacteria density, the apical root canal area is said to be "dangerous" for the pathogenic bacteria, the host and the dentist.

If the root canal is not sufficiently chemomechanical prepared and not replenished with intracanal agents between visits, the synergistic interaction of microbes in the root canal are altered, therefore activating virulence genes of pathogenic strains and that causes increased inflammatory response [3]. Non observance of aseptic rules during the endodontic treatment, poor patient oral hygiene, working without a rubber dam system, uncleaned carious tissue, or old non-hermetic filling, and secondary infection, which may cause post-operation pain and flare up.

Chemical factors

Irrigation solutions, intracanal medicaments, and root fillings used in endodontic treatment may be toxic and can cause chemical irritation and postoperative pain and tenderness after entering the periradicular tissues.

The more filling is pushed out of the root canal and into the periodontal tissue, the more intense inflammatory response [3].

Even though the presence of toxic microorganisms is an important causative factor in the occurrence of flare-ups, it is also accepted that both contaminated and uncontaminated dentine and pulp tissue can trigger an inflammatory reaction [2].

Apical extrusion using file systems-hand and rotary

During root canal instrumentation, necrotic debris, residual pulp tissue, microorganisms, dentin chips, or irrigants can be forced towards the periapical area leading to flare-up.

Evaluating the amount of extruded debris by different instrumentation techniques, we find that nearly all the techniques produce some degree of extrusion. Instrumentation techniques that involve filing movements would generate more apical debris [14] because the file would act as a piston, pumping debris and irrigant solutions towards the periapical area [16]. According to Reddy., *et al*. [17] manual or mechanical instrumentation with rotary movements greatly reduce the amount of debris as these techniques tend to pack the dentin chips within the grooves of the file and expel it from the root canal. Furthermore, both the conical preparation of canal access and the crown-apex technique tend to produce less debris [15].

Among different techniques for biomechanical preparation, the crown-down technique causes less extrusion of debris than hand-instrumentation so it should be chosen as the method of choice for the infected root canals.

Nickel-titanium (NiTi) hand files have a very low modulus of elasticity (MOE), making them 2 - 3 times more elastic compared to stainless steel files. Also due to ductility, NiTi files show higher resistance to torsional fracture [18]. According to the structural characteristics of these devices, their use is likely to reduce the extrusion of debris from the apical end.

Al-Omari and Dummer [19] compared the use of 8 different hand-instrumentation methods and found that techniques involving a filing (linear) motion caused significantly more blockages and extruded significantly more apical dentine debris. Their results were also consistent with other studies, that showed that cervical flaring and crown-down techniques tended to result in less apical extrusion [20].

In general, the design of rotary files along with the motion used tends to direct debris toward the canal orifice, packing the debris into the grooves of the instruments and pushing it outward toward the orifice, thus avoiding their compaction in the root canal [21]. Regarding debris extrusion, variability between different rotary systems in terms of debris extrusion was observed [22]. This is believed to be caused by differences in cross-section and cutting blade design of a particular system as well as taper, tip, configuration, concepts of use, flexibility, alloy, number of files, kinematics, and cutting efficacy [24].

A recent review [25] reported that inflammatory reaction due to debris extrusion is influenced by the type of movement and instrument design. However, there have been conflicting results on motion kinematics and debris extrusion. Several studies reported that reciprocating motion produced more debris than continuous rotating motion, although some of them reported opposite results [25-27]. Instrument systems operated with adaptive motion are relatively new and research in this area is limited.

The amount of apically extruded debris may differ depending on whether the adaptive movement is predominant at the beginning of the instrumentation or at the point of apical refinement [28]. The root canal anatomy, the curvature of the root canal, and particularly the experience of the operator all play decisive roles in the movement kinematics of this system.

The amount of debris extrusion with the TF Adaptive instruments used with continuous rotation was lower than that with reciprocation motions at angles of CW=90°and CCW=30°.

Apical extrusion using irrigants

Removal of vital and necrotic remnants of pulp tissues, microorganisms, and microbial toxins from the root canal system is essential for endodontic success [29-31]. This can be achieved through chemo-mechanical debridement [32-34], but the complex nature of root canal anatomy makes it impossible to completely shape and clean the root canal [35-44]. Using rotary instrumentation [35], currently available nickel-titanium instruments act only on the central body of the canal, leaving canal fins, isthmi and cul-de-sacs untouched after preparation is complete [36-39]. These areas might harbor tissue debris, micro-organisms, and their by-products [41-43], which might prevent close adaptation of the obturation material [39-41] and result in persistent periradicular inflammation [42,43]. Irrigation is therefore an integral part of root canal debridement because it allows for cleaning beyond what might be achieved by root canal instrumentation alone [36,45]. An ideal root canal irrigants should meet all the conditions for successful endodontic treatment described above [46].

However, there is no one unique irrigant that can meet all these requirements, even with the use of methods such as lowering the pH [46-48], increasing the temperature, as well as the addition of surfactants to increase the wetting efficacy of the irrigant. Thus, in contemporary endodontic practice, dual irrigants such as sodium hypochlorite (NaOCl) with ethylenediaminetetraacetic acid (EDTA) or chlorhexidine (CHX) [49] are often used as initial and final rinses to counterpart the shortcomings that are associated with the use of a single irrigant.

Inadvertent injection of sodium hypochlorite beyond the apical foramen may occur in teeth with wide apical foramina or when the apical constriction has been destroyed during root canal preparation or by resorption. Moreover, extreme pressure during irrigation or binding of the irrigation needle tip in the root canal with no release for the irrigant to leave the root canal coronally may result in the commerce of large volumes of the irrigant to the apical tissues. If this occurs, the excellent tissue-dissolving capability of sodium hypochlorite will lead to tissue necrosis [50,51].

A clinical trial that compared postoperative pain after the use of 2% CHX and 5.25% NaOCl reported that the latter solution was significantly associated with more pain [50].

However, during irrigation, low and constant pressure should be used and the operator must ensure that excess irrigant leaves the root canal coronally via the access cavity. However, it has been shown that contact between the periapical tissues and the irrigant cannot be completely avoided [5,51]. Therefore, a dilute concentration of the irrigant that retains sufficient disinfecting properties is recommended.

Apical extrusion using intracanal medicaments

Knowledge of the causes of and the mechanisms behind inter-appointment pain in endodontics is of utmost importance for the clinicians to properly prevent or manage this undesirable condition.

Clinical studies have shown that substances used for irrigation or intracanal medication may not affect the presence of postoperative symptoms. However, severe reactions have been reported after the extrusion of some universally used substances into the periradicular tissues.

Calcium hydroxide $Ca(OH)_2$ has been used in dentistry for almost a century [52]. Its use in root canal treatment as an intracanal medication has been associated with periradicular healing. Although $Ca(OH)_2$ dressing material can inadvertently leak from the apex of the tooth during endodontic treatment, careful $Ca(OH)_2$ dressing placement beyond the confines of the root canal and into the periradicular tissues has also been advocated. Some speculate that this directly affects inflamed tissue and epithelial cystic linings, promoting periapical healing and encourages osseous repair [52]. However, such intentional overextension is not widely supported, as periapical extrusion of $Ca(OH)_2$ can have detrimental effects. Reports of osteonecrosis and persistent inflammatory responses in repaired mechanical perforations [53], the neurotoxic effects of root canal sealers, cytotoxicity on cell cultures, damaged epithelium with or without cellular atypical when applied on hamster cheek pouches, cellular damage after early $Ca(OH)_2$ dressing of avulsed teeth, and necrosis of buccal gingiva and mucosa after periradicular overextension caused by alkaline burn have been presented.

Instrumentation may develop a traumatic communication facilitating the passage of fluids into the artery. Atraumatic canal preparation reduces the likelihood of extruding endodontic material into the periradicular region. The lentulo spiral is the most effective agent in delivering $CaOH_2$ paste to working length and syringe systems are less exact for carrying the filling material [54]. Additionally, there is a greater threat of calcium hydroxide extrusion when using pressure syringe systems.

Apical extrusion during obturation

The main goal of root canal therapy is to thoroughly mechanically and chemically cleanse the entire pulp space and completely occlude it with an inert filling material and a coronal filling, preventing ingress of microorganisms [55]. The filling material can extrude into the periradicular tissues. This causes additional tissue inflammation, neurotoxic effects, and a foreign body reactions [56]. For this reason, the use of biocompatible material has been advocated to avoid extrusions and the ensuing complications [57,58].

Endodontic filling materials can be extruded apically during obturation. Contact with the periradicular tissues might cause complications ranging from mild inflammatory and allergic reactions to neurotoxic effects such as anaesthesia and long-lasting paresthesia [58]. The materials most commonly associated with these complications are compounds that contain paraformaldehyde, calcium hydroxide, and/or eugenol.

Warm gutta-percha best meets the requirements of a root canal filling. This is because homogeneity is provided throughout the entire length of the filling. The various thermoplastic techniques include the Mc Spadden method, ObturaII, Ultrafil, Endotec, and Thermafil. In Obtura II, the gutta-percha is heated from temperatures ranging from 160^0C to 200^0C before injecting it through the needle.

There is controversy in the literature, however, regarding the presence of cement beyond the apex. Several authors, including Schilder (1967), rejected the hypothesis that the presence of cement beyond the apex favors the healing of the periapical lesions, maintaining their benign nature. He argues that extrusion beyond the apex should be avoided only because the patient may experience discomfort during the obturation phase [59].

Other authors have reported substantial cytotoxicity of both commonly used cement, and gutta-percha following research studies carried out *in vitro* with SEM (scanning electron microscope) [60]. Since this cytotoxicity can induce periradicular inflammation or periodontal necrosis, overfilling can lead to short term treatment failure or long-term poor prognosis, thus the possibility should be avoided as far as possible.

Recently, Torabinejad., *et al*. introduced mineral trioxide aggregate (MTA) which provides an effective seal against dentin and cementum and promotes biologic repair and regeneration of the periodontal ligaments. The next logical application of this material could be its use as a tight sealing apical barrier against which the rest of the canal can be obturated without the fear of periapical extrusion [61].

It is advantageous to use MTA as an apical plug as there is no fear of apical extrusion and the root canal system can then be obturated three dimensionally against this barrier using any thermoplasticized gutta-percha obturation technique.

Conclusion

Microbial damage by bacteria and their products that enter the periradicular tissues from the root canal system may be a major cause of inter-appointment flare-ups. All preparation techniques and instruments have been reported to be associated with the extrusion of infected debris, even when preparation is maintained short of the apical terminus.

In general, the clinical relevance and scientific reliability of the reported studies are questionable, making it difficult to draw firm conclusions. When choosing the correct method, apical extrusion alone should not be the decisive factor, as other parameters determine the clinical success of root canal treatment. Prevention of all types of damage and irritation to periradicular tissues is one of the major clinical tasks of a practitioner. Care should be taken in the selection and utilization of instruments, specifically considering the diagnosis of the clinical case.

Bibliography

1. Seltzer S and Naidorf IJ. “Flare-ups in endodontics: I. Etiological factors”. *Journal of Endodontics* 11.11 (1985): 472-478.
2. McKendry DJ. “Comparison of balanced forces, endosonic, and step-back filing instrumentation techniques: quantification of extruded apical debris”. *Journal of Endodontics* 16.1 (1990): 24-27.
3. Tanalp J and Güngör T. “Apical extrusion of debris: a literature review of an inherent occurrence during root canal treatment”. *International Endodontic Journal* 47.3 (2014): 211-221.
4. Chapman CE., *et al*. “A preliminary report on the correlation between apical infection and instrumentation in endodontics”. *International Endodontic Journal* 2.1 (1968): 7-11.
5. VandeVisse JE and Brilliant JD. “Effect of irrigation on the production of extruded material at the root apex during instrumentation”. *Journal of Endodontics* 1.7 (1975): 243-246.
6. Siqueira JrJF. “Microbial causes of endodontic flare-ups”. *International Endodontic Journal* 36.7 (2003): 453-463.

7. Huang X., *et al*. "Quantitative evaluation of debris extruded apically by using ProTaper Universal Tulsa rotary system in endodontic retreatment". *Journal of Endodontics* 33.9 (2007): 1102-1105.

8. Siqueira JrJF and Barnett F. "Interappointment pain: mechanisms, diagnosis, and treatment". *Endodontic Topics* 7.1 (2004): 93-109.

9. Elnaghy AM and Elsaka SE. "Evaluation of root canal transportation, centering ratio and remaining dentin thickness associated with ProTaper Next instruments with and without glide path". *Journal of Endodontics* 40.12 (2014): 2053-2056.

10. Zanette F., *et al*. "Apical root canal transportation and remaining dentin thickness associated with ProTaper Universal with and without PathFile". *Journal of Endodontics* 40.5 (2014): 688-693.

11. Berutti E., *et al*. "Use of nickel-titanium rotary PathFile to create the glide path: comparison with manual preflaring in simulated root canals". *Journal of Endodontics* 35.3 (2009): 408-412.

12. Leonardi LE., *et al*. "Apical extrusion of debris by manual and mechanical instrumentation". *Brazilian Dental Journal* 18.1 (2007): 16-19.

13. Elmsallati EA., *et al*. "Extrusion of debris after use of rotary nickel-titanium files with different pitch: a pilot study". *Australian Endodontic Journal* 35.2 (2009): 65-69.

14. Altundasar E., *et al*. "Debris and irrigant extrusion potential of 2 rotary systems and irrigation needles". *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* 112.4 (2011): e31-e35.

15. Fairbourn DR., *et al*. "The effect of four preparation techniques on the amount of apically extruded debris". *Journal of Endodontics* 13.3 (1987): 102-108.

16. Brown DC., *et al*. "An in vitro study of apical extrusion of sodium hypochlorite during endodontic canal preparation". *Journal of Endodontics* 21.12 (1995): 587-591.

17. Reddy SA and Hicks ML. "Apical extrusion of debris using two hand and two rotary instrumentation techniques". *Journal of Endodontics* 24.3 (1998): 180-183.

18. Myers GL and Montgomery S. "A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques". *Journal of Endodontics* 17.6 (1991): 275-279.

19. Al-Omari MA and Dummer PM. "Canal blockage and debris extrusion with eight preparation techniques". *Journal of Endodontics* 21.3 (1995): 154-158.

20. Fairbourn DR., *et al*. "The effect of four preparation techniques on the amount of apically extruded debris". *Journal of Endodontics* 13.3 (1987): 102-108.

21. Plotino G., *et al*. "Deformation and fracture incidence of R eciproc instruments: a clinical evaluation". *International Endodontic Journal* 48.2 (2015): 199-205.

22. Moghadam KN., *et al*. "Canal transportation and centering ability of twisted file and reciproc: a cone-beam computed tomography assessment". *Iranian Endodontic Journal* 9.3 (2014): 174.

23. Lloyd A., *et al*. "Shaping ability of the M4 handpiece and Safety Hedstrom Files in simulated root canals". *International Endodontic Journal* 30.1 (1997): 16-24.

24. De Carvalho Maciel AC and Zaccaro Scelza MF. "Efficacy of automated versus hand instrumentation during root canal retreatment: an ex vivo study". *International Endodontic Journal* 39.10 (2006): 779-784.

25. Caviedes-Bucheli J., *et al*. "The influence of two reciprocating single-file and two rotary-file systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. A systematic review and meta-analysis". *International Endodontic Journal* 49.3 (2016): 255-270.

26. Arslan H., *et al*. "Comparison of apically extruded debris after root canal instrumentation using Reciproc® instruments with various kinematics". *International Endodontic Journal* 49.3 (2016): 307-310.

27. Topçuoğlu HS., *et al*. "Influence of a glide path on apical extrusion of debris during canal preparation using single-file systems in curved canals". *International Endodontic Journal* 49.6 (2016): 599-603.

28. Karataş E., *et al*. "Quantitative evaluation of apically extruded debris with Twisted File Adaptive instruments in straight root canals: reciprocation with different angles, adaptive motion and continuous rotation". *International Endodontic Journal* 49.4 (2016): 382-385.

29. Gambarini G., *et al*. "Influence of different angles of reciprocation on the cyclic fatigue of nickel-titanium endodontic instruments". *Journal of Endodontics* 38.10 (2012): 1408-1411.

30. Siqueira Jr JF and Rôças IN. "Clinical implications and microbiology of bacterial persistence after treatment procedures". *Journal of Endodontics* 34.11 (2008): 1291-1301.

31. Wong R. "Conventional endodontic failure and retreatment". *Dental Clinics of North America* 48.1 (2004): 265-289.

32. Basmadjian-Charles CL., *et al*. "Factors influencing the long-term results of endodontic treatment: a review of the literature". *International Dental Journal* 52.2 (2002): 81-86.

33. Sjögren UL., *et al*. "Factors affecting the long-term results of endodontic treatment". *Journal of Endodontics* 16.10 (1990): 498-504.

34. European Society of Endodontology. "Consensus report of the European Society of Endodontology on quality guidelines for endodontic treatment". *International Endodontic Journal* 27.3 (1994): 115-124.

35. Ricardo S and Nursasongko B. "Comparison of Apical Third Cleanliness of Smear Layer Using Endoactivator® and Vibringe®". *Journal of International Dental and Medical Research* 9.3 (2016).

36. Gutarts R., *et al*. "In vivo debridement efficacy of ultrasonic irrigation following hand-rotary instrumentation in human mandibular molars". *Journal of Endodontics* 31.3 (2005): 166-170.

37. Svec TA and Harrison JW. "Chemomechanical removal of pulpal and dentinal debris with sodium hypochlorite and hydrogen peroxide vs normal saline solution". *Journal of Endodontics* 3.2 (1977): 49-53.

38. Walton RE. "Histologic evaluation of different methods of enlarging the pulp canal space". *Journal of Endodontics* 2.10 (1967): 304-311.

39. Haga CS. "Microscopic Measurements of Root Canal Preparations Following In strumentation". *International Endodontic Journal* 2.3 (1968): 41-46.

40. Gutie JH. "Microscopic and macroscopic investigation on results of mechanical preparation of root canals". *Oral Surgery, Oral Medicine, Oral Pathology* 25.1 (1968): 108-116.

41. Shuping GB., *et al*. "Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications". *Journal of Endodontics* 26.12 (2000): 751-755.

42. Card SJ., *et al*. "The effectiveness of increased apical enlargement in reducing intracanal bacteria". *Journal of Endodontics* 28.11 (2002): 779-783.

43. Fariniuk LF., *et al*. "Histologic analysis of the cleaning capacity of mechanical endodontic instruments activated by the ENDOflash system". *Journal of Endodontics* 29.10 (2003): 651-653.

44. Ferreira RB., *et al*. "Histological Analysis of The Cleaning Capacity of Nickel-Titanium Rotary Instrumentation with Ultrasonic Irrigation In Root Canals". *Australian Endodontic Journal* 30.2 (2004): 56-58.

45. Gulabivala K., *et al*. "Effects of mechanical and chemical procedures on root canal surfaces". *Endodontic Topics* 10.1 (2005): 103-122.

46. Zehnder M. "Root canal irrigants". *Journal of Endodontics* 32.5 (2006): 389-398.

47. Cotter JL., *et al*. "Chemical parameters, antimicrobial activities, and tissue toxicity of 0.1 and 0.5% sodium hypochlorite solutions". *Antimicrobial Agents and Chemotherapy* 28.1 (1985): 118-122.

48. Christensen CE., *et al*. "Effect of lowering the pH of sodium hypochlorite on dissolving tissue in vitro". *Journal of Endodontics* 34.4 (2008): 449-452.

49. Cunningham WT and Balekjian AY. "Effect of temperature on collagen-dissolving ability of sodium hypochlorite endodontic irrigant". *Oral Surgery, Oral Medicine, Oral Pathology* 49.2 (1980): 175-177.

50. Ringel AM., *et al*. "In vivo evaluation of chlorhexidine gluconate solution and sodium hypochlorite solution as root canal irrigants". *Journal of Endodontics* 8.5 (1982): 200-204.

51. Hülsmann M and Hahn W. "Complications during root canal irrigation–literature review and case reports". *International Endodontic Journal* 33.3 (2000): 186-193.

52. Sjögren U., *et al*. "The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing". *International Endodontic Journal* 24.3 (1991): 119-125.

53. Alaçam T., *et al*. "Cytotoxicity versus antibacterial activity of some antiseptics in vitro". *The Journal of Nihon University School of Dentistry* 35.1 (1993): 22-27.

54. Sigurdsson A., *et al*. "Intracanal placement of Ca (OH) 2: a comparison of techniques". *Journal of Endodontics* 18.8 (1992): 367-370.

55. Seltzer S and Naidorf IJ. "Flare-ups in endodontics: I. Etiological factors". *Journal of Endodontics* 11.11 (1985): 472-478.

56. Serper A., *et al*. "Comparative neurotoxic effects of root canal filling materials on rat sciatic nerve". *Journal of Endodontics* 24.9 (1998): 592-594.

57. Yoshimine Y., *et al*. "In vitro comparison of the biocompatibility of mineral trioxide aggregate, 4META/MMA-TBB resin, and Intermediate Restorative Material as root-end–filling materials". *Journal of Endodontics* 33.9 (2007): 1066-1069.

58. Gorduysus M., *et al*. "Cytotoxic effects of four different endodontic materials in human periodontal ligament fibroblasts". *Journal of Endodontics* 33.12 (2007): 1450-1454.

59. Schilder H. "Filling root canals in three dimensions". *Dental Clinics of North America* (1967): 723-744.

60. Gutierrez JH., *et al*. "Human teeth with periapical pathosis after overinstrumentation and overfilling of the root canals: a scanning electron microscopic study". *International Endodontic Journal* 32.1 (1999): 40-48.

61. Torabinejad M., *et al*. "Sealing ability of a mineral trioxide aggregate when used as a root end filling material". *Journal of Endodontics* 19.12 (1993): 591-595.

Volume 21 Issue 11 November 2022