Foraminal enlargement analysis

Drs. Carlos Henrique Ferrari, Frederico Canato Martinho, Ricardo Machado, and Leticia Aguiar analyze the benefits and risks of intentional foraminal enlargement, considering the impact both locally and systemically.

In recent years, endodontics has seen a considerable paradigm shift as a result of technical and scientific developments. However, the concept of shaping and cleaning (Schilder, 1974) remains one of the pillars of the specialty especially when dealing with infected canals.

Historically, the literature has demonstrated how anatomical complexities make it so difficult to adequately shape and clean the root canal system, especially the apical one-third (Paqué, et al., 2009; Paqué, et al., 2010). Furthermore, in some cases, endodontic infection extends beyond the limits of the apical constriction, for example, to the apical foramen or beyond (extraradical biofilm) (Noiri, et al., 2002; Chavez De Paz, 2007; Ricucci, Siqueira Jr, 2010). In these situations, intentional foraminal enlargement may be performed to decrease the microbial load to levels more favorable for repair (Borlina, et al., 2010). Previous studies have shown encouraging results for intentional foraminal enlargement, enabling more efficient mechanical action of instruments and the chemical action of irrigating solutions (de Souza Filho, et al., 1987).

Therefore, the purpose of this paper was to perform a critical literature review by analyzing the likely benefits and risks of intentional foraminal enlargement, considering the impact both locally and systemically.

Local effects

Anatomical considerations

Undeniably, pulp necrosis and peri-radicular lesions are an indication that the entire length of the root canal is contaminated (Ricucci, Siqueira Jr, 2010, Tronstad, et al., 1990; Nair, et al., 2005, Siqueira, Rôças 2008). For this reason, the literature has postulated that apical patency can clear the apical foramen and promote microbiological disruption in this area, using a small caliber instrument to lightly touch the walls of the apical foramen (Buchanan, 1989; Caillietteau, Mullaney, 1997; Flanders, 2002; Souza 2006; Coutinho–Filho, et al., 2012; Mounce, 2015). However, intentional foraminal enlargement is performed with different techniques and instruments and consists of the mechanical enlargement of the apical foramen for the purpose of decontamination by excising infected dentin and cementum (Borlina, et al., 2010; Silva, et al., 2013). Accurate intentional foraminal enlargement requires the shape and diameter of the apical foramen to be accurately assessed and measured. Clinically, this would seem to be impossible (Dummer, et al., 1984; Abarca, et al., 2014). Conventional endodontic instruments are unable to perform this, because of the oval shape of the apical foramen (Goldberg, Massone, 2002; Marroquin, et al., 2004; Herrera, et al., 2011; Aksise, et al., 2014). Consequently, adequate cleaning cannot be achieved (Wu, et al., 2000; Marroquin, et al., 2004; Abarca, et al., 2014).

Several clinical studies have shown a high frequency of instrument fracture in the apical third when anatomically complex and narrow canals are present (Ehrhardt, et al., 2012; Madarati, et al., 2013). Moreover, especially when dealing with posterior teeth, the apical foramen may be located laterally to the anatomical apex (Pineda, Kuttler, 1972), and intentional foraminal enlargement may predispose to weakening of the tooth with a higher incidence of fracture.

Another factor limiting foraminal enlargement is the clinician’s inability to achieve apical potency of the apical foramen in some situations. This may occur because of abrupt curvatures, the existence of two or more main apical foramina, apical deltas, or complete or incomplete isthmuses (Meder–Cowherd, et al., 2011; Verma, Love, 2011; Villas–Bôas, et al., 2011).

Considering all the facts and appreciating that foraminal enlargement is a plausible idea from a microbiological standpoint, it cannot always be performed. In controlled clinical studies with robust samples and appropriate inclusion and exclusion criteria (Imura, et al., 2007; Ricucci, et al., 2011; Liang, et al., 2013), there have been no reports of intentional foraminal enlargement in the clinical protocols adopted. Nonetheless, the success rates of these studies are high even in cases of pulp necrosis with radiographically visible peri-radicular disease (Imura, et al., 2007; Ricucci, et al., 2011; Liang, et al., 2013).

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Extrusion of sodium hypochlorite, calcium hydroxide, and filling materials

Sodium hypochlorite is the most widely accepted and used irrigant solution worldwide (Stojicic, et al., 2010; Zou, et al., 2010; Wong, et al., 2014; Guneser, et al., 2015). Nonetheless, it has a highly adverse effect after extrusion into the periapical tissues or maxillary sinus, or when injected into the gingival mucosa (Pashley, et al., 1985; Gatot, et al., 1991; Ehrich, et al., 1993; Kavanagh, et al., 1998; Kleier, et al., 2008; de Sêmero, et al., 2009; Wang, et al., 2010; Kerbi, et al., 2012).

The most common consequences of this type of accident are the following: (Hulsman, Hahn, 2000; Serper, et al., 2004).
- severe pain
- instant inflammation of the affected area
- swelling extended to the face, lips, and infraorbital region
- hemorrhage descending from the root canal
- interstitial hemorrhage with skin and mucosa bruising
- secondary infection, paresthesia

The use of calcium hydroxide as an interappointment dressing can have adverse consequences if it is accidentally extruded beyond the apical foramen (Fava, 1993; Marais, Van Der Vyver, 1996). Fava (1993) as well as Marais and Van Der Vyver (1996) reported cases of calcium hydroxide extrusion into the maxillary sinus, causing acute pain and a foreign body reaction. Ahlgren, et al., (2003) reported a case of calcium hydroxide extrusion into the mandibular canal with acute pain and paresthesia. Other adverse consequences associated with the extrusion of calcium hydroxide are neural injury (Clsen, et al., 2014), severe periapical inflammation requiring the extraction of the involved tooth (Hanson, Maduskev, 2013), and the persistence of periapical lesions (Ionnidis, et al., 2010).

Certain filling materials (mainly solids) are also responsible for several extrusion-related complications, such as radiographically visible foreign body reactions, flares-up, and postoperative pain exacerbated by the activation of an inflammatory response (Oliet, 1983; Rowe, 1983; Georgopoulos, et al., 1987; Siqueira, 2003; Nair, 2004; Saleh, et al., 2004; Seltzer, Naidorf, 1985; Gluskin, 2005; Köseoglu, et al., 2006; González-Martín, et al., 2004; Faria-Júnior et al., 2013; Alves, et al., 2014). All materials extruded beyond the apical foramen are irritating to the periapical tissues to a greater or lesser extent. There is no scientific evidence warranting the intentional extrusion of irrigating solutions, pastes, and cements (Strindberg, 1956; Engstrom, 1964; Yusuf, 1982; Nair, et al., 1990; Sjögren, et al., 1990; Orstavik, Hørsted–Bindseil, 1993).

It is important to consider the hypothesis that the greater the enlargement of the apical foramen, the greater the possibility of extrusion of any substance used in the root canal (Hülsmann, Hahn, 2000). Nevertheless, more research is required to confirm this hypothesis.

Systemic effects

Patients who are taking or have taken bisphosphonates recently

Bisphosphonates are drugs used to treat bone diseases and prevent tumour metastasis (Moinzadeh, et al., 2013). Their extensive use is directly related to osteonecrosis of the jaw after performing dental procedures (Katz, 2005; Sarathy, et al., 2005; Edwards, et al., 2008; Moinzadeh, et al., 2013). Since these drugs are widely used today, dentists should be knowledgeable about some likely effects that can influence the prognosis of the treatment.

Specifically related to endodontics, some important precautions should be borne in mind:
- Antiseptics, such as chlorhexidine, must be used to reduce the bacterial load of the oral cavity (Cousido, et al., 2010) and the risk of bacteraemia, due to possible injury to soft tissues during the course of treatment (Moinzadeh, et al., 2013)
- Anesthetics with vasoconstrictors should be avoided because the vasculature is compromised, constituting a greater risk for osteonecrosis, as bisphosphonates exert an antiangiogenic effect (Tarassoff, Csermak, 2003; Soltau, et al., 2008; Moinzadeh, et al., 2013).
- Special care must be taken to reduce damage to the gingival tissue (Kyrigidis, Vahtsevanos, 2009; Moinzadeh, et al., 2013)
- Filling techniques must be prioritized to pose the lowest risk of overfilling and overextension (Liang, et al., 2011; Moinzadeh, et al., 2013)

According to Katz (2005) and Edwards, et al., (2008), one of the main precautions in relation to patients who are making use or have recently made use of this class of drug is to establish a working length near the apical constriction and to decrease the extrusion of debris and exacerbated inflammatory reactions during and after treatment. Even foraminal patency should be avoided (Moinzadeh, et al., 2013) because it can considerably increase the chances of bacteremia (Debelian, et al., 1995; Moinzadeh, et al., 2013). These statements are based on bisphosphonates interfering directly with the bone remodeling process and inhibit the chemical mediators of the inflammatory process (Katz, 2005; Edwards, et al., 2008).

When considering the need for endodontics in patients who are or have been using bisphosphonates recently, it seems obvious that intentional foraminal enlargement is a completely contraindicated procedure.

Patients with coagulation disorders or using anticoagulants

Homeostasis in healthy patients is associated with four main factors:
- Blood vessel walls
- Blood platelets
- The coagulation system
- The fibrinolytic system

Blood vessel constriction is the first stage, followed by platelet adhesion and aggregation, and by fibrin deposition. In the next stage, the coagulation process is regulated by physiologic anticoagulants. Activation of fibrinolysis is triggered by the presence of fibrin and tissue plasminogen activator-types at the site of fibrin formation, a process regulated by physiologic inhibitors such as 2-antiplasmin, histidine-rich glycoprotein, and plasminogen activator inhibitor (DeLoughery, 1999; Scully, Wolff, 2002).

This process is completely different in patients with a coagulopathy or taking anticoagulants because of the risk of excessive bleeding, even from a gentle stimulus. Gingival bleeding during tooth cleaning may cause these patients to neglect their oral health, thus increasing the risk of periodontal disease and caries. For this reason, dentists should be knowledgeable about the impact of blood disorders or the use of anticoagulants in treating these patients (Johnson, Leary, 1988; Shapiro, McKown, 1990; Gupta, et al., 2007).

In patients with coagulation disorders or taking anticoagulants, and needing tooth extraction, conventional endodontic treatment or retreatment should be the preferred option whenever possible. However, the shaping and cleaning process must be confined to the limits of the root canal (Chohayeb, 1981), and intentional foraminal enlargement would be completely contraindicated.

Patients with a high risk of bacteremia

Several systemic complications from oral infections have been reported. Some of the most common include bacterial endocarditis; myocardial infarction; cerebral abscess; bone, antral, and bloodstream...
infections (Baumgartner et al., 1976; McGowan, 1982; Bender, Montgomery, 1986; Debelian, et al., 1994; Murray, Saunders, 2000; Scully, et al., 2003).

During endodontic treatment, the shaping and cleaning procedure has the potential to contaminate the bloodstream and the lymphatic system with bacteria (Bender, et al., 1980; Baumgartner, et al., 1976; Seymour, et al., 2000; Fouad, 2009).

Blood samples collected from patients during and after endodontic treatment of teeth with pulp necrosis revealed the presence of the same bacteria in both the root canal system and the bloodstream (Heimdahl, et al., 1990; Debelian, et al., 1995; Debelian, et al., 1998; Savarino, et al., 2005). Therefore, microorganisms from the root canal can be carried to and then settle in locations distant from their place of origin (Fouad, 2009).

The extrusion of debris during shaping and cleaning of the root canal system has frequently been shown, regardless of the systems and techniques used (Reddy, Hicks, 1998; Bürklein, Schäfer, 2012; Koçak, et al., 2013; Kirchhoff, et al., 2015).

Tinaz, et al., (2005) conducted a study for the specific purpose of correlating debris extrusion and the apical limit of instrumentation. It compared the extrusion of debris during manual and rotary instrumentation in teeth that had intentionally enlarged apical constriction and apical foramen. Fifty-two teeth were divided into two groups with 26 specimens each, in accordance with the instrumentation technique used (manually instrumentation using K-files or rotary instrumentation using ProFile .04 taper series 29). The teeth were further divided into two subgroups, with intentional enlargement of the apical foramen by K-files No.15 and No.30, 2 mm beyond the apical foramen. The irrigating solution was 2.6% sodium hypochlorite. No statistically significant differences between using manual and rotary instrumentation were found in relation to the extruded debris. However, both techniques showed a strong tendency to produce greater amounts of debris when the apical constriction and the apical foramen were intentionally enlarged.

Hence, instrumentation beyond the apical foramen should be avoided in patients at high risk for bacteremia, considering the greater risk for systemic spread of microorganisms (Debelian, et al., 1995; Seymour, et al., 2000; Siqura, Roca, 2008; Hülsman, Schäfer, 2009; Baumann, Beer, 2011). Consequently, a wider

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17. González-Martín M, Torres-Lagares D, Gutiérrez-Pérez JL, Mercado G. Debris remaining in the apical third of root canals during shaping and cleaning of the root canal system has frequently been shown, regardless of the systems and techniques used (Reddy, Hicks, 1998; Bürklein, Schäfer, 2012; Koçak, et al., 2013; Kirchhoff, et al., 2015).
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variety of techniques have been recom-
mended to achieve more effective action from endodontic instruments (Olivieri, et al., 2014; Sant’Anna Júnior, et al., 2014) and irrigating solutions (van der Sluis, et al., 2007; Brunson, et al., 2010).

There are occasions when endodontic infection extends beyond the limits of the apical constriction — i.e., to the apical foramen or even beyond (extraradicular biofilm) (Norí, et al., 2002; Cheave De Paz, 2007; Ricucci, Siqurra Jr, 2010). In these situations, intentional foraminal enlargement is designed to reduce the microbial load in these areas to levels more favorable for repair (Borlin, et al., 2010). However, it must be pointed out that, to date, there have been only animal studies comparing the success rates between intentional foraminal enlargement and conventional instrumentation limits (close to the apical constriction) (Holland, et al., 1979; Borlin, et al., 2010). Even considering the positive results of these studies, there is no way to infer that this procedure will have the same positive biological responses in humans.

According to the precepts of scientific evidence-based dentistry, certain criteria must be respected and followed prior to any interventions in humans. First, laboratory studies should be performed to construct a plausible hypothesis to be tested in vivo. Then in vivo animal studies should be performed to observe any toxic or harmful potential of the substances, drugs, or intervention. Ultimately, longitudinal, controlled clinical studies are needed to observe the results and confirm possible advantages or disadvantages related to the previously considered hypothesis (Seymour, et al., 2003; Miller, Forrest, 2009; Kwok, et al., 2012).

When it comes to the question of intentional foraminal enlargement, there is no scientific evidence to support its use. To date, no randomized clinical trial has been conducted with longitudinal follow-ups, evaluating the success rates of endodontic treatments or retreatments where the apical limits of instrumentation were established for the apical foramen or beyond. On the other hand, high success rates have been reported for apical limits of instrumentation established close to the apical constriction in controlled clinical studies with robust samples and appropriate inclusion and exclusion criteria (Imura, et al., 2007; Ricucci, et al., 2011; Liang, et al., 2010).

From a scientific perspective, it is obvious that the impacts of intentional foraminal enlargement on the success of endodontic therapy should be evaluated. However, the methodology of these studies should be even more carefully designed, insofar as the literature reviewed in this paper reiterates that this procedure poses both local and systemic risks to the patient.