Irrigation dynamics in root canal therapy

By Prof. Anil Kishen, Canada

Irrigation dynamics deals with the process of irrigant flow, penetration, exchange and the forces produced within the root canal space. Current modes of endodontic irrigation include the traditional syringe needle irrigation or physical methods, such as apical negative-pressure irrigation or sonic/ultrasonically assisted irrigation. Since the nature of irrigation influences the flow of irrigant up to the working length (WL) and interaction of irrigant with the canal wall, it is mandatory to understand the irrigation dynamics associated with various irrigation techniques.

Endodontic irrigants are liquid antimicrobials used to disinfect bacterial biofilms within the root canal. The process of delivery of endodontic irrigants within the root canal is called irrigation. The overall objectives of root canal irrigation are to inactivate bacterial biofilms, inactivate endotoxins, and dissolve tissue remnants and debris (chemical effects) in the root canals, as well as to allow the flow of irrigant entirely through the root canal system, in order to detach the biofilm structures and loosen and flush out the debris from the root canals (physical effects). While the chemical effectiveness will be influenced by the concentration of the antimicrobial and the duration of action, the physical effectiveness will depend upon the ability of irrigation to generate optimum streaming forces within the entire root canal system.

The final efficiency of endodontic instrumentation will depend upon both chemical and physical effectiveness. It is important to realise that even the most powerful irrigant will be of no use if it cannot penetrate the apical portion of the root canal, interact with the root canal wall and exchange frequently within the root canal system.

**Syringe irrigation**

Irrigation methods are categorised as positive-pressure or negative-pressure, according to the mode of delivery employed. In positive-pressure techniques, the pressure difference necessary for irrigant flow is created between a pressurised container (e.g. a syringe) and the root canal. In negative-pressure techniques, the irrigant is delivered passively near the canal orifice and a suction tip (negative-layer chemical effects) in the root canals, as well as to allow the flow of irrigant through the root canal system.

The flow of irrigants is influenced by the physical characteristics, such as density and viscosity. These properties for the commonly used endodontic irrigants are very similar to those of distilled water. The surface tension of endodontic irrigants and its decrease by surfactants have also been studied extensively. The rationale of this combination is that it may significantly affect (a) the irrigant penetration into dentinal tubules and accessory root canals and (b) the dissolution of pulp tissue. However, it is important to note that surface tension would only influence the interface between two immiscible fluids, and not between the irrigant and dentinal fluid.

*Experiments have confirmed that surfactants do not enhance the ability of sodium hypochlorite to dissolve pulp tissue (a) or the ability of chelating agents to remove the smear layer (b).*

The type of needle used has a significant effect on the flow pattern formed within the root canal, while parameters such as depth of needle insertion and size or taper of the prepared root canal have only a limited influence. Generally, the available needles can be classified as closed-ended and open-ended needles. In the case of open-ended needles (flat, bevelled, notched), the irrigant stream is very intense and extends apically along the root canal. Depending upon the root canal geometry and the depth of needle insertion, reverse flow of irrigant occurs near the canal wall towards the canal orifice.

In the case of closed-ended needles (side-vented), the stream of irrigant is formed near the apical side of the outlet and is directed apically. The irrigant tends to follow a curved route around the needle tip, towards the canal orifice. The flow of irrigant apical to the needle outlet is generally observed to be a passive fluid flowing zone (dead zone), while the flow of irrigant in the remaining aspect of the root canal is observed to be an active fluid flowing zone (active zone; Figs. 1a-d & 2a-d). A series of vortices of flowing irrigant are generated apical to the tip. The velocity of irrigant inside each vortex decreases towards the apex.

Large needles when used within the root canal hardly penetrate beyond the coronal half of the root canal. Currently, smaller-diameter needles (25–29 gauge) have been recommended for root canal irrigation. This is mainly because of their ability to advance further up to the WL. This facilitates better irrigant exchange and debridement. In addition, the use of a larger needle would result in decreased space available for the flow of irrigant between the needle and the canal wall. This scenario has been associated with (a) an increased apical pressure for open-ended needles and (b) decreased irrigant refreshment apical to the tip for closed-ended needles.

The influence of tooth location (mandibular, maxillary) on irrigant flow has been observed to be minor.

**Irrigator refreshment**

Irrigator exchange in the root canal system is a key prerequisite for achieving optimum chemical effect, because the chemical efficacy of the irrigants is known to be rapidly inactivated by dentine, tissue remnants and debris. Investigations have explained the limitations in the irrigant refreshment apical to needles. Enlarging the root canal to place the needle to a few millimetres from the WL, and ensuring adequate space around the needle for reverse flow of the irrigant towards the canal orifice allow effective irrigant refreshment coronal to the needle tip. Furthermore, increasing the
The effect of curvature on irrigant exchange has been studied indirectly by Nguy and Sedgley. They report that only severe curvatures in the order of 24–28° hampered the flow of irrigants. If the canal is enlarged to at least size 30 or 35 and a 30-gauge flexible needle placed near the WL is used, then irrigant refreshment can be expected even in severely curved canals.

Wall shear stress

The frictional stress that occurs between the flowing irrigant and the canal wall is termed “wall shear stress”. This force is of relevance in root canal irrigation because it tends to detach microbial biofilm from the root canal wall. Currently, there is no quantitative data on the minimum shear stress required for the removal of microbial biofilm from the canal wall. Yet, the nature of wall shear stresses produced within the root canals during irrigation provides an indication of the mechanical debridement efficacy. In open-ended needles, an area of increased shear wall stresses develops apical to the needle tips, while in closed-ended needles, a higher maximum shear stress is generated near the tips on the wall facing the needle outlet. Thus, in open- and closed-ended needles, optimum debridement is expected near the tip of the needle. Consequently, it is necessary to move the needle inside the root canal, so that the limited area of high wall shear stress involves as much of the root canal wall as possible. The maximum shear stress decreases with an increase in canal size or taper. Thus, overzealous root canal enlargement above a certain size or taper could diminish the debridement efficacy of irrigation (Figs. 1a–d & 2a–d).

Fluid dynamics studies on apical negative-pressure irrigation have demonstrated maximum apical penetration of the irrigant, without any irrigant extrusion. This finding highlights the ability of apical negative-pressure irrigation to be safely used at the WL, circumventing the issues of vapour lock effect. Nonetheless, the apical negative-pressure irrigation produced the lowest wall shear stress. This decrease in the wall shear stress could be attributed in part to the reduction in the flow rate with this irrigation system.

Enhancing irrigation dynamics using physical irrigation methods

Passive ultrasonically assisted irrigation, when compared with other irrigation methods, showed the highest wall shear stress along the root canal wall, with the highest turbulence intensity travelling coronal from the ultrasonic tip position. The lateral movement of the irrigant displayed by this method has important implications with respect to its ability to permit better interaction between the irrigant and the root canal wall, and to potentially enhance the interaction of irrigants with intra-canal biofilms (Figs. 1a–d & 2a–d).

Conclusion

The requirements of adequate irrigant penetration, irrigant exchange, mechanical effect and minimum risk of apical extrusion oppose each other and a subtle equilibrium is required during irrigation. Ideally, in a canal enlarged to size 30 or 35 and taper 0.04 or 0.06, an open-ended needle should be placed 2 or 3 mm short of the WL to ensure adequate irrigant exchange and high wall shear stress, while reducing the risk of extrusion.

In the case of a closed-ended needle, placement should be within 1 mm short of the WL, so that optimum irrigant exchange can be ensured. The apical negative-pressure irrigation did not generate marked wall shear stress values, but allowed the flow of irrigant consistently up to the WL. It was the safest mode of irrigation when used close to the WL. The passive ultrasonically assisted irrigation generated the highest wall shear stress. The use of combined methods to obtain optimum disinfection and to circumvent the limitations of one method is recommended.
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Use of mineral trioxide aggregate in endodontic retro-filling

By Fernanda Maria Klimpel, Brazil

Mineral trioxide aggregate (MTA) is an endodontic sealer that emerged on the market in 1998. Through proven scientific results it has become the true miracle of endodontics. An excellent sealing material, it provides setting expansion and integrity of the seal owing to low solubility, tissue biocompatibility and high biological regeneration. The release of calcium ions provides antibacterial activity. Its radiopacity is excellent, and it can be used for thermal condensation owing to its melting point of 150 °C.

MTA also has good capacity for adhesion to dentine, making it resistant to the forces of displacement, and greater sealing power than other cements when tested to assess the quantity of bacterial infiltration. It is indicated for treatment of perforations in the furcation region, of internal resorption, and of root perforations via surgery when it is impossible to treat the perforation via the canal or treatment has been unsuccessful, for use in para-endodontic surgery as a retro-filling material, and for direct pulp protection, pulpotomy, apexogenesis and apexitification.

Literature review

MTA is a biocompatible material with numerous clinical applications in endodontics. It was first used experimentally by Lee and Monsel. However, approval of its use in humans by the American Dental Federation was not granted until 1998.

It is composed primarily of tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide, as well as a small quantity of other mineral oxides and the addition of bismuth oxide, which is responsible for the material’s radiopacity. The principal molecules present in MTA are calcium and phosphorus ions, which are also the main components of dental tissue, giving MTA excellent bonding to its melting point of 150 °C.

Both brands of MTA have been significantly evaluated and no other material has shown more progressive results.

According to Poza et al., the use of MTA in cavity walls, unlike other materials, achieves the best seal against infiltration. Different materials have been used to seal the path connecting the root canal and the para-endodontic tissue. However, none of them have achieved results as promising as those of MTA and various studies have proven that MTA is the best on the market today. According to Leal, MTA cement has effective sealing capacity.

According to Bernabé et al., conventional endodontic treatment is not able to resolve some cases and para-endodontic surgery is required to obtain a good result. The filling material used must not be toxic or mutagenic, and has to be biocompatible and insoluble. The material used in retro-filling distinguishes a good para-endodontic surgery from a bad one. MTA achieves the best result specifically for sealing between the tooth and external surface.

Endodontic treatment has become more practical owing to the new methods and techniques, with the emergence of materials with excellent physical and biological properties. The literature deals with various materials used in retro-filling, but generally speaking these materials do not have all the requisite properties to be able to remain in the cavity, such as biocompatibility, radiopacity, insolvability in periapical fluids, easy compounding, non-staining of the periradicular tissue, good adaptation and sealing capacity. An ideal material to replace amalgam should offer adhesion, promote hermetic sealing, be biocompatible, be radiopaque, be easy to compound and provide for an environment favourable for tissue regeneration.

According to Hellwig et al., para-endodontic surgeries expose and remove dental apices, promote retro-cavitations along the axis of the root canals and retro-fill them with materials that promote their sealing. Para-endodontic surgery is an excellent option for conservative treatment of teeth with chronic periapical lesions, and treatment by the conventional method is impractical in some cases.

According to Jacobovitz et al., treatment of inflammatory resorption must be directed at combating endodontic infection. In certain cases, clinical resolution using conventional endodontic treatment can become unfeasible owing to the difficulties of performing instrumentation and adequate full...
Para-endodontic surgeries have various procedural methods that aim to resolve failures or accidents that occur in conventional endodontic treatment.20 According to Girardi et al., apicectomy is a method of para-endodontic surgery that entails the separation of the apical portion from the root.16 It is performed when there is no regression of the apical lesion after the alternatives of conventional endodontic therapy have been exhausted in an attempt to eliminate the apical micro-organisms and their toxic products.

The use of a high-quality retro-filling material is indispensable, if an inferior quality material is used, an increase in apical infiltration may occur, since the dentinal tubules are more exposed by certain cutting angles and permeability is hence increased, and this is important at the time of applying the filling material.11

According to Oliveira et al., in an apicectomy with retro-filling using MTA and monitoring after five years, it was observed that teeth with a persistent periapical fistula, after having undergone a suitable endodontic treatment, the surgical retreatment with retro-filling may be an efficient option in the resolution of the infection and repair of the periapical tissue.46

The literature confirms that MTA presents excellent physical, chemical and biological properties, which justify it as the material of choice in the treatment of radicular resorption. It is a material that, compared with other restorative materials, has less microleakage and is capable of inducing the formation of mineralised tissue, such as bone, dentine and cementum, owing to it reaching a pH plateau of around 12.5 in 3 hours. According to Costa et al., who analysed the clinical application of MTA in relation to radicular resorption, in cases in which radicular resorption is minimal, the canal is filled with calcium hydroxide to stimulate the repair, closing the access cavity with zinc oxide and eugenol.49

Among the various advantages of MTA is minimal radiopacity, which has proven to be an important criterion and contributes to it being considered the best choice by the dental surgeon in relation to biomaterials to be used in para-endodontic surgery.50

According to Barros and Araújo Filho, MTA has been used successfully in filling the apical space of the root canal. In addition to its excellent sealing capacity, it is biocompatible with the peri-radicular tissue, and induces the formation of cementoblasts and osteoblasts.66

Clinical case

This case illustrates the use of MTA for sealing the root perforation and the effectiveness of the retro-filling material after apicectomy (additional surgery, Figs. 1-17). A 31-year-old patient presented to the Universidade Tuiuti do Paraná dental clinic (Brazil) complaining about a gap in the gingiva above tooth #11, from which a large quantity of purulent discharge was draining. In the radiographic examination, an extensive radiolucent area was found, indicating a fistula (periapical lesion) involving the periapical region of the tooth in question.

During the endodontic treatment, the secretion into the tooth could not be controlled. Even 23 days after treatment, with changes to the intra-canal medication, the fistula returned and the exudate drainage via the canal persisted. Definitive sealing of the root perforation was then opted for, utilising MTA and continuing with changes of calcium hydroxide in the root canal. Owing to the persistence of the exudate via the canal, it was decided to perform endodontic filling, followed by supplementary surgical treatment (apicectomy) with retro-filling with MTA, conserving the tooth structure as much as possible.

The surgery was performed under local anaesthetic with an infra-orbital nerve block and supplementary infiltrative anaesthesia at the apex of the tooth, as well as a nasopalatine nerve block. The anaesthesia used was 3% mepivacaine with 1:100000 adrenaline.

The incision was made with a #15 scalpel blade and a flap was raised. The osteotomy was performed with a high-speed drill of the 700 series in order to gain access to the periapical region. The lesion was curetted with a short curette. An apicectomy was performed with the drill and 2 mm of the apex was removed. The cavity for retro-filling was prepared with a spherical drill under constant irrigation with saline solution, and then the retro-filling with MTA was performed. After condensation of the material in the cavity, the excess was removed with a periodontal curette. Finally, the flap was repositioned and then sutured.

One 750 mg pill of acetaminophen every 6 hours for two days was prescribed. In the seven-day postoperative control period, the patient had no symptoms incompatible with the surgery performed and the healing appeared normal. These circumstances held for the full monitoring period, over the course of a year, as the radiograph one year after treatment established new bone formation in the region, proving the success of the case. At the end of the surgical treatment, the patient was referred for prosthetic treatment.

Conclusion

According to the methodology used in this case and considering its results, it can be concluded that the MTA material used was efficient in the formation of a new mineralised tissue barrier, completely sealing the apical portion of the canal.

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The objective of endodontic treatment is the elimination of pulp debris or the bacterial biofilm and its toxins from the root canal system in order to prevent or eliminate any periapical lesion. For this purpose, root canal shaping is an essential, necessary and complex step. Essential because it allows indispensable irrigation, necessary to achieve a D obturation of the endodontic root canal system and complex because of the infinite complexity of the root canal anatomy.

Over the past several years, the definition of an endodontically successful root canal treatment has changed considerably. In 1986, success was based on the complete disappearance of the periapical lesion. In 2004, the concept evolved and the terms “recovered tooth” and “diseased tooth” were used. In 2011, the terminology of “functional tooth” versus “non-functional tooth” was finally introduced. Despite this, the concepts for root canal shaping established by Schilder in 1974 remain unchanged, namely with respect to the initial root canal anatomy and position of the apical foramen, as well as conservation of root canal patency and obtention of a sufficient taper to guarantee the penetration of the irrigating solutions to the apex.

Practitioners are familiar with these concepts and try to implement them in the best possible way. However, endodontic treatment remains an area that poses great difficulties for dental surgeons, and time constraints can often lead to inadequate treatments. Thus, general practitioners desire a simple, efficient and rapid solution that allows reproducible results. The introduction of rotary nickel–titanium (NiTi) instruments in endodontics in the late 1980s has revolutionised the discipline. The material’s extreme elasticity imparts great flexibility to instruments with greater diameters and tapers than those of hand files. Stainless-steel hand files are more rigid and can lead to the creation of an apical ledge, canal transportation, a crack in the apical foramen or even instrument fracture.

Although NiTi instruments allow reliable and reproducible results, they present a higher risk of fracture than do stainless-steel files, particularly those used in continuous rotation, which is due to cyclic fatigue or higher torsional stress. Instrument fractures caused by cyclic fatigue occur without prior deformation visible to the naked eye. They are therefore impossible to foresee with certainty.

Too often does this elevated risk of instrument fracture result in general practitioners abandoning endodontics altogether. However, respecting several simple principles, such as using the speed and torque recommended by the instrument manufacturer, pre-enlarging the root canal, using vertical up-and-down movements, as well as cleaning and performing visual control of the instrument after each passage, makes the practitioner’s work less stressful and more relaxed.

The introduction of single-use instruments not only eliminates the risk of cross-contamination, but also considerably reduces the risk of instrument fracture due to cyclic fatigue and simplifies the operating procedure. MICRO-MEGA has designed the One Shape Procedure Pack, which contains an ENDOFLARE file, a #10 MMC file, a One G file and a One Shape file. It simplifies the operating procedure, removes the need for instrument maintenance and makes stock management easier. All of the necessary instruments for the endodontic treatment are single-use files supplied in sterile packaging.

Operating procedure

Each endodontic treatment requires a preoperative radiograph taken with a radiograph film holder. Once a dental dam has been placed and the access cavity has been prepared, the root canal entrances are localised and the pulp chamber is irrigated with sodium hypochlorite.

The first step of the root canal preparation is the enlargement of the canal entrances. As the first instrument in the One Shape Procedure Pack, ENDOFLARE (with a diameter of 0.23 and a 0.12 taper) is used with up-and-down movements and pressure on the canal walls in the first 3–4 mm of the root canal to enlarge the canal orifices. In this case, ENDOFLARE eliminates the dentinal overhang at the entrance to the distal root canal (Fig. 4) and lays open the second mesiobuccal canal (Fig. 5).

Fig. 1: One Shape Procedure Pack.—Fig. 2: Pre-op radiograph of tooth #17.—Fig. 3: Opening of the pulp chamber (P: palatal canal; DB: distobuccal canal; MB: mesiobuccal canal).—Fig. 4: Elimination of overhang with ENDOFLARE (P: palatal canal; DB: distobuccal canal; MB: mesiobuccal canal).—Fig. 5: After the passage of ENDOFLARE, access to the distobuccal canal is straightened (P: palatal canal; DB: distobuccal canal; MB: first mesiobuccal canal; MB: second mesiobuccal canal).—Fig. 6: Exploration file, #10 MMC, in the distobuccal canal.—Fig. 7: One G.—Fig. 8: Radiograph of One G in the second mesiobuccal canal.
The exploration file (size MMC) serves to evaluate the root canal’s complexity. It is introduced into the root canal without axial constraints in the coronal zone, owing to the previous action of ENDOD-LARE. Any coronal interference that might hinder the file’s passage must be eliminated to make the treatment as safe as possible (Fig. 6).

The second step of the root canal preparation is the exploration of the root canal and the creation of a glide path. This step entails the pre-enlargement of the root canal and facilitates the passage of the following rotary shaping instrument. Root canal exploration and glide path development are performed with stainless-steel hand files or rotary NiTi files. It has been shown that the use of a highly flexible instrument with an asymmetrical cross-section reduces the risk of canal transportation. In addition, this kind of cross-section, combined with a variable helical pitch diminishes screwing effects.

The second rotary instrument in the One Shape Procedure Pack is One G (Fig. 7). This NiTi instrument has a diameter of 0.14 and a 0.09 taper has an asymmetrical cross-section. Its three cutting edges are situated on three different radii to the root canal axis. One G also has a variable helical pitch and thus variable helical angles. The narrower the angle, the more active the rotating instrument, and the wider the angle, the greater the efficiency of the instrument’s traction. All of these features provide One G with a high flexibility and great efficiency.

Clinically, if the root canal is patent, One G is taken to the working length (WL) previously determined with the #10 MMC file and an apex locator. However, if the root canal is not patent, One G penetrates with vertical up-and-down movements on the canal axis down to the length attained by the #10 MMC file. This allows the elimination of constraints in the cervical and middle thirds of the canal. The #10 file is then pre-curved in order to check the canal patency. The WL is determined and transferred to One G, which is then taken to the WL at a speed of 350–450 rpm and a maximum torque of 2.5 Ncm (Figs. 8 & 9). After the creation of the glide path with One G, the #15 MMC file must penetrate down to the WL without constraints. The root canal is now ready for shaping.

The third rotary instrument is One Shape (Fig. 10). This NiTi instrument with a diameter of 0.23 and a 0.06 taper has a variable cross-section. The apical 2 mm of its active blade with a global length of 16 mm has a triple-helix cross-section with three cutting edges situated on three different radii to the canal axis. The following 7.5 mm constitutes a transitional zone that terminates in a double-helix section of 0.6 mm in the coronal part of the file.

The cutting effect of the two cutting angles in the coronal zone is more important and allows more efficient elimination of the debris, whereas the three cutting angles in the apical zone provide the instrument with a better centring ability, a higher resistance to torsional constraints and a better capacity to negotiate curves. The instrument’s tip is inactive and allows for a smooth progression in the root canal. The helical pitch and angle are variable along the instrument and thus guarantee a better upward transport of the debris and limit screwing effects. Owing to its characteristics, One Shape causes less extrusion of debris and irrigating solution in the apical zone than other single-file systems available on the market.

The instrument progresses with an up-and-down movement of low amplitude and without excessive pressure. One Shape is used in continuous rotation with a speed of 350–450 rpm and a maximum torque of 2.5 Ncm. Root canal shaping is performed in three steps with progression of One Shape to two-thirds of the WL, 3 mm short of the WL, and the WL (Fig. 11). Between each passage, the root canal is abundantly irrigated with sodium hypochlorite and patency is checked with a file. The instrument’s spires must be systematically cleaned and visually inspected.

One Shape performs the root canal preparation quicker than other single-file systems. This gain in time must be used for the indispensable final irrigation.

Editorial note: A list of references is available from the publisher.

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