The foundation of minimally invasive endodontics: research, technology, and technique

Dr. Stephen R. Ottosen discusses new directions that allow endodontists to experience greater success and long-term value for patients

Introduction

The triad of bacterial-related disease in dentistry consists of coronal decay, periodontal infection, and endodontic infection. These have common traits, similarities, and differences. All have at their origin biofilm.

With coronal decay, the primary traits of the bacteria involved are the production of extracellular polysaccharides from sucrose to allow adhesion to the tooth surface and each other. They also digest sugars and produce lactic acid. The combination of plaque and acid leads to tooth decay.

In advanced periodontal disease, the bacteria involved primarily produce an extracellular matrix to allow adhesion to the root surface and toxins that promote inflammation of the surrounding tissue.

Endodontic infections are the result of pulpal necrosis and the accompanying bacterial colonization of the pulp space. The dominant bacteria in the canal space inhabit biofilm (Figure 1) formed by the production of extracellular polymeric substances (EPS). The bacteria within the pulpal space produce various toxins. These include endotoxin (lipopolysaccharide [LPS]), exotoxin, and short chain fatty acids.

The major difference among these biofilms found in the mouth is the ability of the coronal biofilms to produce acid and physically break down the tooth structure. This results in the need for removal of destroyed enamel and dentin during treatment (restoration) of the coronal hard tissue (Figure 3).

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Disclosure: Dr. Ottosen is the founder and president of MicroEndo. He can be reached at (509)664-6669, steve@ottoendo.com or by visiting www.microendosolutions.com.

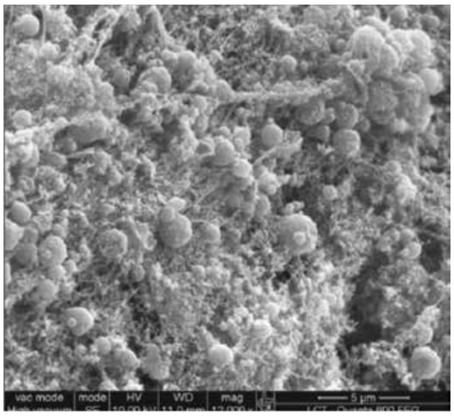

Figure 1: Endodontic biofilm

With periodontal disease, the root surface is contaminated but generally not carious. The goal is to remove the biofilm to allow the inflammation to decrease. Further treatment of the root surface is needed to allow reattachment of the connective tissue.

In endodontic infections, the dentin and accompanying isthmuses and accessory canals are contaminated by the bacteria. These are areas that are inaccessible to endodontic files during canal instrumentation and preparation. Caries or significant demineralization or structural degradation of the dentin is not found (Figure 3). Ideal treatment would be to remove the bacteria and their associated EPS and toxins and to leave the dentin intact.

Irrigation

As 35%[1] or more of the canal walls are not touched by instrumentation during endodontic treatment, we are very reliant upon irrigation to clean the pulpal space.

The following irrigation techniques generally use sodium hypochlorite 5% and EDTA 17%. Sodium hypochlorite (NaOCl) proved to be the most effective endodontic irrigant because of its excellent antimicrobial efficiency, biofilm disruption, organic tissue dissolution, and debris removal properties.[2,3,4,5] EDTA, a chelator, is used during root canal therapy to remove the inorganic component of the smear layer produced by instrumentation.[6] Its biofilm-dispersing

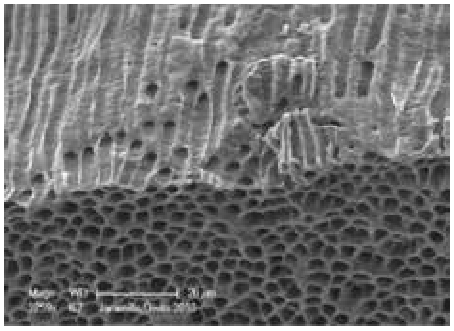

Figure 2: Dentin after PIPS-activated irrigation

Figure 3: Coronal biofilm byproduct: decay. Canal space biofilm byproduct: apical periodontitis.

property[7,8] means that EDTA can also be used to "loosen" or clean endodontic biofilms. The recommended protocol for irrigation includes the use of sodium hypochlorite (NaOCl) during mechanical preparation to dissolve the organic matter and kill microorganisms followed by a chelating agent such as EDTA to remove the smear layer and to leave an adequate substrate for optimal efficacy of the final irrigant.[9,10]

Small gauge side-vented irrigation needle and negative pressure irrigation systems are effective in cleaning the main canal space coronal to the depth of needle placement.[13] These techniques provide good columnar irrigant flow with decrease incidence of apical extrusion of irrigants into the periapical tissue.

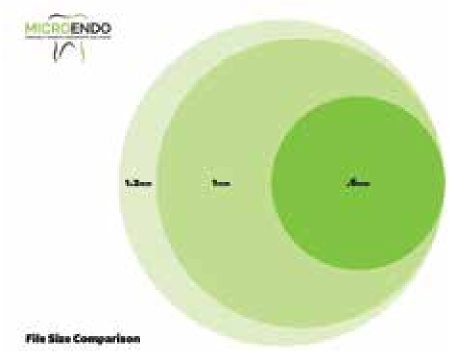

Figure 4: File cross section comparison.

Turbulent flow of irrigant is needed to reach anatomy that extends away from the main canal.[14] Additionally, frequent exchange of irrigant assists in removing debris from the canal system adjacent to the main canals.

Sonic and ultrasonic metal and non-metal points are effective at creating turbulence, but their effectiveness is greatly diminished when they contact the canal wall.[15] Upon contact with the canal wall, their energy is dampened and does not transmit efficiently through the irrigation solution. Metal ultrasonics are prone to breakage. Ultrasonics can gouge the canal wall.[16]

Erbium Yag (Er:YAG) lasers[17] and sound wave[18] irrigation activation systems are very effective (Figure 2). Both of these systems are effective due to their ability to impart energy and thus movement of the irritants within the canal system. The Fotona Erbium Yag laser performing the PIPS (Photon Induced Photo Acoustic Streaming) technique results in irrigant flow 20 to 100 times faster than ultrasonic techniques.[19] PIPS is based on the activation of liquid irrigants by medium-infrared laser (2,940 Nm). The tip is placed inside the pulp chamber only. The technique uses a radial firing and stripped tip, allowing lateral emission of laser energy in the liquids. The use of subablative energy (20 mJ) delivered in a very short time (pulse duration of 50 microseconds) produces a high peak power of 400 W, causing an explosion-implosion phenomenon within the irrigant solution. The result is a strong photo-acoustic shock wave that induces irrigant streaming three-dimensionally throughout the entire root canal system while avoiding any direct laser irradiation on the dentin and consequent unwanted thermal effects.[11,12] The irrigant activation reaches over 20 mm away from the tip compared to only 2 mm for ultrasonics.[19]

Blade or "wing" type rotary irrigation instruments have shown good results in research studies.[20] Easy Clean (Easy Equipamentos Odontologicos; Belo Horizonte, Brazil) has a blade design that is used in large angle reciprocation or complete rotation. The MicroIrrigator (MicroEndo LLC, Wenatchee, Washington) has a wing design (Figure 5) with a twist down the long axis. It is used in a reciprocating hand piece. This design provides turbulence as well as rapid slight positive and negative pressure.

Instrumentation

As instrumentation alone is ineffective at cleaning the canal system, its main function is debridement of the canal and creating, when necessary, a pathway for irrigation.

The more a canal is tapered, flared, or enlarged at the coronal portion, the weaker the root becomes.[21] Rotary instruments with a taper greater than 4% (.04) have consistently shown to create small dentin defects or cracks in research studies.[22,23] These cracks are suspected to lead to root fractures. The higher the torque used in rotary instrumentation, the higher the incidence of dentin cracks.[24] Reciprocating techniques used with tapered files create dentin cracks at a higher incidence than a traditional rotary technique.[25] This may be partially due to the large changes in file dimensions between files used in these techniques and the resulting high torques created.

The amount of dentin removed during instrumentation is directly correlated with the cross section of the rotary instruments used. The area of the circle scribed by the cross section of the instrument is found by the formula πr^2. Thus, the radius of the instrument dramatically effects the amount of dentin removed during instrumentation. Most endodontic file systems have a very tapered design. This usually results in a maximum flute diameter of 1.0 mm-1.2 mm. Path Glider™ (Komet; Rock Hill, South Carolina) and MicroFiles (MicroEndo; Wenatchee, Washington) (Figure 5) have a low taper (2%-3%) design with a maximum flute diameter of 0.6 mm. When instrumenting a calcified canal, a standard rotary file may remove 200%-300% more dentin in the coronal portion of the canal (Figure 4). These small diameter files require much less torque to operate.

A recent long-term recall study of an endodontic specialty practice demonstrated less incidence of vertical root fracture in endodontically treated teeth with less tapered canal preparations.[30]

Finite element analysis has demonstrated that dentin preservation at the cervical area of the tooth is most important in retaining tooth strength under occlusal forces.[31]

Obturation

Ideally, obturation is achieved with 3D adaptation of gutta percha to the canal

Figure 5: (left to right) Komet PathGlider 20, MicroEndo MicroFile 20, Pro Taper Next X1, MicroEndo MicroIrrigator 27

anatomy and a thin layer of sealer between the gutta percha (GP) and dentin.[26] The only way to adapt GP to complex anatomy is through heat and pressure.[27] GP only conducts heat ~4 mm ahead of a heated instrument tip. This has led to various heating techniques. Most techniques involve placing a heated metal instrument into the GP and then down packing the warmed GP with a smaller cool metal instrument. Unfortunately, the root canal has to be enlarged to accommodate the metal heating and packing instruments. These instruments rarely reach the apical area in curved or small canals to provide a closely adapted GP/sealer/dentin interface.[27]

Carrier-based systems have been widely used. They often do not provide a gutta-percha apical seal.[28] The carrier provides a variety of challenges, and apical stripping of the warmed GP from the carrier is a common occurrence during insertion, resulting in carrier contact with the apical canal wall with no intervening GP. Mechanical (rotary) heating and compaction of gutta percha has been shown to be very effective.[29]

MicroObturators (MicroEndo) use a reverse wound rotary obturator (Figure 6) to place warm gutta percha into the canal and then compact the GP to form an ideal seal regardless of canal shape. The MicroObturators are able to obturate very small canals. If Erbium Yag (PIPS/Fotona) or multisonic (Sonendo®, Laguna Hills, California) systems are used, instrumentation is sometimes unnecessary with rotary or hand files. The MicroObturator technique uses an Obtura (Kerr, Orange, California) type backfill device to cover the obturator with warm low

Figure 6: Irrisonic tip and Easy Equipmentos Odontologicos Easy Clean irrigator

Figure 7: MicroObturator being coated in warm gutta percha

Figure 8: Applying sealer to warm gutta percha

Figure 9: MicroObturator placed to working length (1 mm short of apical foramen)

viscosity gutta percha (Figure 7). The obturator and GP are then coated at its apical half in sealer (Figure 8) and placed into the canal 1 mm from the apical foramen (Figure 9). The obturator is then rotated at 20,000 rpm and withdrawn from the canal. This results in the GP on the rotary instrument being adapted to the canal of the root, and an ideal seal results.

Cases

Case 1 (Figures 10-12)

Tooth No. 30 was diagnosed with pulpal necrosis and chronic apical periodontitis. The canal anatomy was uncomplex with one broad distal canal and two mesial canals that joined. Very little root dentin was removed to debride the canals. A size 20 .03 PathGlider (Komet) was used as the final instrument. The canal system was cleaned with Er-Yag

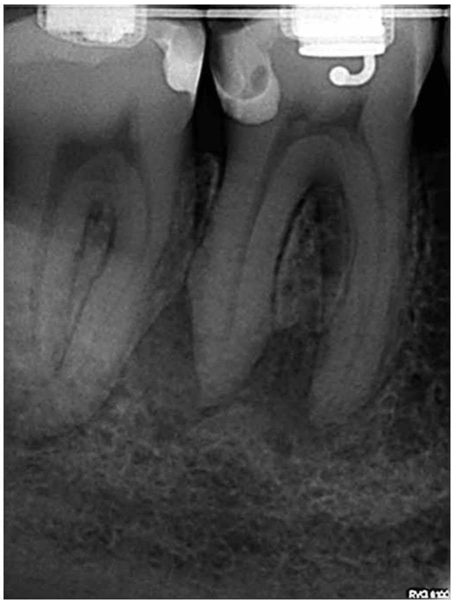

Figure 10: Case 1 — pre-op radiograph

Figure 11: Case 1 — post-op radiograph

Figure 12: Case1 — 1-year recall radiograph

Figure 13: Case 2 — pre-op radiograph

Figure 14: Case 2 — post-op radiograph

Figure 15: Case 3 — pre-op radiograph

Figure 16: Case 3 — post-op radiograph

laser-activated irrigation (Fotona). Obturation was completed with a size 16 MicroObtuator (MicroEndo), NanoFlow (Healthdent Technology Intl., Inc.; Palmdale, California) gutta percha and Kerr Pulp Canal Sealer EWT. Ideal healing was seen at 1-year follow-up.

Case 2 (Figures 13-14)

Tooth No. 4 was diagnosed with pulpal necrosis and acute apical periodontitis. After access, No. 4 was irrigated with PIPS, dried with paper points, and obturated with a MicroObturator size 16. NanoFlow gutta percha and Kerr EWT sealer were used. No instrumentation was needed due to the size of the existing canal space.

Case 3 (Figures 15-16)

Tooth No. 3 was diagnosed with pulpal necrosis and acute apical periodontitis. The palatal canal was instrumented to a size 35 .02 MicroFile (MicroEndo); the mesial and distal buccal canals to a size 30.02 MicroFile. Irrigation was completed with Er-Yag laser-activated irrigation. Obturation was completed with a MicroObturator size 16. NanoFlow gutta percha and Kerr EWT sealer were used.

Summary

For the past 30-plus years, the techniques associated with endodontic treatment have been focused on creating tapered canals to allow adequate cleansing and obturation. With new irrigation and obturation techniques, creating these tapers and the associated tooth weakening is no longer necessary (Figure 17). Preservation of cervical tooth structure maintains the strength of the area of the tooth, which under

Figure 17: Cracked mesial root No. 18

Figure 18: No. 31 endodontically treated with minimally invasive techniques

occlusal loading has the highest stress. Thus, conservative instrumentation in the cervical area of the canals does not weaken the tooth as may happen with more aggressive instrumentation (Figure 18).

We are at an amazing time when new techniques, technology, and understanding allow us to step away from previously held beliefs and perceptions. We can move in new directions that will allow us to experience greater success and long-term value for our patients and ourselves. Most importantly, the time is now! EP

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