Received: 11th May 2014 Accepted: 15th August 2014 Conflict of Interest: None

Source of Support: Nil

Review Article

Microleakage in Endodontics

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How to cite the article:

Muliyar S, Shameem KA, Thankachan RP, Francis PG, Jayapalan CS, Hafiz KA. Microleakage in endodontics. J Int Oral Health 2014;6(6):99-104.

Abstract:

A three-dimensional obturation and complete coronal and apical seal is one the important aims of root canal treatment. Since microorganisms may remain in the root canal system after instrumentation, a tight apical seal is desired to prevent bacteria and their by-products from invading the apex. A perfect apical seal is also desired to prevent apical percolation. One of the major objectives of tooth restoration is the protection of exposed dentine against bacteria and their toxins. The interface between the restoration and dental hard tissue is an area of clinical concern as insufficient sealing can result in marginal discoloration, secondary caries, and pulpitis. For that reason, adequate sealing is essential for the optimal clinical performance Prevention of microleakage in endodontically treated teeth is most important for patients who rely on the combined expertise and quality care of dentist/endodontist colleagues. Microleakage is arguably the single most important risk factor for apical periodontitis.

Key Words: Dentin, interface, microleakage, secondary caries

Introduction

Innovations in materials, equipments and techniques continue to sophisticate endodontic treatment procedures enhancing the incidence of predictable clinical success. However, in spite of these advances, clinical failures/shortcomings still persist.[1] Concept of microleakage having an effect on the outcome of endodontic treatment has been known for more than 100 years.[2]

Early endodontic research focused on the quality of endodontic treatment to ensure long-term success and the effects of microleakage on endodontic treatments outcomes.[2]

Microleakage is defined as the "diffusion of the bacteria, oral fluids, ions and molecules into the tooth and the filling material interface" OR "defined as the clinically undetectable passage of bacteria, fluids, molecules or ions between tooth and the restorative or filling material." Many studies emphasize that tooth filling materials are not fixed, inert and impenetrable borders but dynamic micro crevices, which contain busy traffic of bacteria, ions, and molecules.

This leakage may be clinically undetectable but is a major factor influencing the long-term success of endodontic therapy as it causes many severe biological effects leading to recurrence of the pathology and failure of the root canal treatment.

Leakage at micron level (bacterial leakage)

It can be inferred from the above microleakage definition that, marginal gaps around a restoration permit bacteria to pass into the tooth/restoration interface.

This is considered to be bacterial microleakage, which is seen at micron level. Numerous studies have shown that once cariogenic bacteria gain access into the tooth/restorative interface they are able to successfully proliferate along this area with the potential to cause an adverse response from the pulp and recurrent caries.

However, it is still questionable about the marginal gap size around the restorations and occurrence of recurrent caries. It is also reported that recurrent caries rate significantly increases with the extent of wide marginal gap. The origin of bacteria that are found at the tooth/material interface is still uncertain, and their relation to the development of recurrent infection remains to be established. It is believed that bacteria trapped within the smear layer can multiply and cause recontamination of the root canal system through microleakage.

Leakage at submicron level (nanoleakage)

It can also be interpreted that endodontic filling materials or restorations with marginal gaps that permit ions and molecules to gain access can have microleakage at nanolevel. It has been reported that the passage of fluid through dentin is affected by dentin permeability that is markedly influenced by number of factors including volume of dentinal tubules, dentin smear layer, dentin calcification and topical applications.

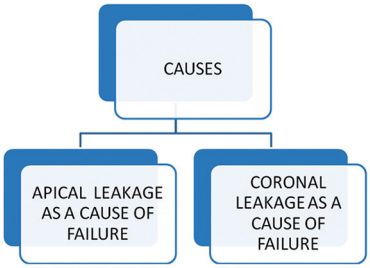
Causes of microleakage

Failure of the root canal treatment may be attributed to a number of factors, but microleakage through the root canal system is one of the major factors.

Numerous studies have examined this phenomenon, identified many sources of possible contamination and emphasized the role of the clinician in preventing microleakage following root canal therapy.

The progression of microleakage is due to long-term biochemical reaction within the material itself and between the material and surrounding environment.

Causes can be broadly divided into:



Methods to detect coronal and apical leakage

Microleakage present inside root canals may remain active in the dentinal tubules even after vigorous chemical-mechanical preparation. Thus, perfect apical sealing is desirable to prevent the remaining bacteria and their endotoxins from reaching the root apex.

Apical leakage is considered to be the common cause for endodontic failure and is influenced by many variables such as different filling techniques, chemical and physical properties of root canal filling materials and presence and absence of smear layer.

In coronal leakage, the canal may be recontaminated in various ways such as contact between the oral bacterial flora and root canal tubule inlets. However, it most frequently occurs due to loss of temporary filling material or inadequate endodontic permanent restoration or crown sealing.[3]

Various methods used for detection of microleakage

- Dye penetration
- Fluid filtration
- Dye extraction or dissolution method
- Bacteria and toxin infiltration method
- Air pressure method
- Electrochemical method
- Neuron activation method
- Radioisotope method
- Metal solution tracers
- Reverse diffusion method
- Artificial caries
- Three-dimensional method
  - In addition, other methods such as:
    - Scanning electron microscopy
    - Transmission electron microscope
    - Micro-computed tomography.[3,4]

Effect of Temporary Restorative Material

The bacteria-tight temporary seal of the endodontic access cavity is an important step of root canal treatment. The importance of a bacteria-tight restoration for the success of an endodontic treatment has been shown in several investigations.[5]

Many clinical infected canals require dressing with antiseptic medicaments in a multi-visit treatment in which elective temporization for different periods of time becomes mandatory.[6]

Absence of acceptable temporary restorations during endodontic therapy ranked second amongst the causative factors in ongoing pain after commencement of treatment.[5] By contrast, permeable temporary fillings have been responsible for persistent post-operative complaints in 80% of cases; they also can negatively influence the prognosis of treatment.[5]

Therefore, removing all bacteria from the tooth should be the main principles of endodontic treatments and then attempting to maintain the tooth in this disinfected state by preventing any further ingress of bacteria during and after treatment.[5]

Therefore, an ideal temporary restorative material must fulfill the following requirements (according to anusavice):

- Bacteria-tight seal of the access to the root canals to avoid infection or reinfection
- Prevention of seepage of intracanal medications into the oral cavity
- Stabilization of the residual tooth structure in order to decrease the
  - Susceptibility of cusp or crown fracture
- Good resistance to abrasion and pressure
- Dimensional stability
- Simple application and removal
- Good esthetic properties
- Have easily identifiable margins
- Adhere to tooth structure–
- Be able to replicate tooth contours for allowing ease of cleaning and maintain space,
- It should have a reasonable degree of moisture tolerance during subgingival marginal placement,
- It should be adhered to stainless steel,
- Have an extensive shelf life, and
- Require only minimal tooth preparation prior to placement.[5,7]

Effect of Instrumentation on Microleakage

- It is axiomatic that "well-shaped canals" produce "well packed canals." Consistently producing shape is one of the strategic cornerstones in the foundation of endodontic success.[8]
- A fundamental aim of endodontic treatment is to prevent or cure apical periodontitis. In teeth with apical periodontitis, bacteria invade and settle into whole root canal system and treatment is shift toward the removal of microorganisms from the root canal system and prevention of reinfection. Biomechanical preparation, disinfection, and obturation altogether constitute equally important phases of endodontic treatment.[8]
- The components of the smear layer can be forced into the dentinal tubules to varying distances.[9]
- Cengiz *et al.* (1990) projected that the incursion of smear material into dentinal tubules could also be caused by capillary action as a result of adhesive forces between the dentinal tubules and the material.[10]
- Inadequate removal of debris and smear layer material can induce stresses on the cutting segment of endodontic instruments. Their removal depends not only on the irrigation method, but also on the endodontic instrument.[8]
- Inadequate elimination of debris and smear layer material can stimulate stresses on the cutting segment of endodontic instruments.[8]
- In general, the use of hand Ni-Ti K flex resulted in significant more remaining debris and smear layer compared to rotary race and flex master instruments[11,12]
- Smear layer formation were highest for ProTaper instrumentation in coronal, middle and apical third smear layer formation were least for EndoWave instrumentation in coronal, middle, and apical third.[8]

Effect of Irrigation on Microleakage

Unfortunately, the mechanical action of instruments is unable to reach areas of the root-canal system due to anatomical complexities. As a result, irrigating solutions have an important role in chemo-mechanical preparation.[13]

The ultimate aim of root canal instrumentation and irrigation is to prepare a clean, bacteria and debris – free canal for obturation. Ingle believes most unsuccessful cases of root canal treatment are caused by percolation of fluid from inflamed periapical tissue into improperly obturated canals.[14]

McComb and Smith reported the formation of a layer of sludge material (smear layer) over the surfaces of instrumented root canal walls. The removal of smear layer has been the subject of controversy for several years.[14]

Many authors have demonstrated that canal surfaces without a smear layer permit penetration of filling materials into patent dentinal tubules, increasing the contact surface, improving mechanical retention and reducing the possibility of microleakage through the filled canal independently of the obturation technique.[15]

According to Torabinejad *et al,* (smear layer) is one of the factors that can adversely affect the apical and coronal microleakage compromising the long-term success of the treatment. These unwanted layers of organic and inorganic materials should be removed before obturation of the root canal system.[16]

Haapasalo *et al*., suggest that removal of the smear layer can allow intracanal medicaments to penetrate the dentinal tubules in infected root canals more readily and consequently cause a better disinfection procedure. On the other hand, smear layer may prevent unwanted bacterial activities by sealing the bacteria into the dentinal tubules; it also blocks the entry of bacteria in contaminated canals into the dentinal tubules, thus acting as a barrier against the free movement of bacteria into or out of open dentinal tubules.[14]

One purpose of the irrigation is to remove the smear layer from instrumented canal walls. Irrigation with ethylenediaminetetraacetic acid (EDTA) alone can only remove the inorganic portion of smear layer. Therefore to eliminate smear layer completely, it should be combined with an organic solvent such as NaOCl.[14]

Irrigation with 1% NaOCl combined with 17% EDTA had the least mean coronal microleakage after obturation.[15]

Dogan and Qalt (2001), concluded that, characteristics of CHX-treated dentin might also explain the greater resistance to microbial leakage. Different irrigation regimens may alter the chemical and structural composition of dentin, thereby affecting the adhesion of bonded materials to the dentin surface. The presence of surface surfactant in CHX increases the surface energy and wetting ability of dentin. This may positively affect the adhesion of hydrophilic bonded materials like ActiV GP and Epiphany.[17]

Removing the smear layer and the demineralization of peritubular dentin leaves the dentinal tubules widely open causing the penetration and mechanical locking of sealer into dentinal tubules and increasing the adhesion surface area between canal walls and filling materials. This shows that the apical seal is significantly increased when smear layer is removed thus reducing microleakage.[14]

Torabinejad *et al.* (2003), conducted a study and concluded that samples with smear layer had more leakage than samples that had the smear layer removed with EDTA or mixture of tetracycline, an acid and a detergent (MTAD), although this difference was statistically significant only with the latter. Increased coronal leakage in samples treated with EDTA

compared with those treated with MTAD might be caused by the erosive property of EDTA and the length of dentin exposure to this solution. Studies have shown that EDTA is destructive in the coronal and middle thirds of root canals if left for more than 1 min in contact with the root dentin.[18,19]

Park *et al*. have shown that MTAD is effective as a final rinse to remove the smear layer, and it also is capable of eradicating bacteria from infected root canals. In addition, they found that MTAD is a biocompatible material and has minimal effects on the physical properties of the tooth. The results of the present investigation showed that the use of this irrigant as recommended, does not adversely affect the seal of gutta-percha and AH Plus.[18]

Effect of Sealers on Microleakage

The three-dimensional obturation of the root canal system is widely accepted as a key factor for successful endodontic therapy. Schilder states, "The objective of root canal procedures should be the total three-dimensional filling of the root canal and all accessory canals." A three-dimensional well-fitted root canal prevents percolation and microleakage of periapical exudates into the root canal space, prevents reinfection, and creates a favorable biological environment for healing to take place.[20]

Root canal sealers

Besides proper cleaning and shaping of the root canal, the complete and hermetic obturation of the root canal system is a major objective in root-canal treatment.[21] The sealing ability of the sealers used plays an important role in achieving this goal.[22] Sealing generally includes the use of a semisolid material (gutta-percha) and sealing cement; the gutta-percha serves as the core-filling material, whereas the root canal sealer is required to adhere to dentin and fill the discrepancies between the core-filling material and the dentinal walls.

Work reported by Dow and Ingle and Ingle *et al.* the latter in the so-called "Washington study" suggested that apical percolation of periradicular exudate into the incompletely filled root canal accounted for approximately 60% of endodontic failure.[21]

Most popular sealers are zinc-oxide eugenol formulations, calcium hydroxide sealers, glass inomers, and resins.[23]

There are many formulations and brands of sealers that have zinc oxide as the primary ingredient, differing only by other components added to the sealers e.g.; Grossmans sealer, Rickert's sealer, Tubli-seal, Wach's sealer.[23]

Orstavik (2005) has given various parameters for testing endodontic sealers and evaluation of microleakage. Weine studied the influence of root canal shape (curved or straight) on the sealing ability of sealers in fluid transport models and concluded that seal apex allowed more leakage then pulp canal sealer.

Cobankara *et al*. (2001) quantitatively evaluated the sealing ability four sealers Rocanal, a zinx oxide-eugenol powder-liquid system, A H Plus, and epoxy resin based sealer. Apical leakage decreased gradually for all sealers from 7 to 21 days. Seal apex demonstrated better apical sealing then other sealers.[23]

Lucena-Martin (2002) performed an *in vitro* study to assess the apical sealing afforded by three cements – Endomethasone, Top Seal, and Roeko Seal – based on the utilization of two different techniques: Clearing and cross-sectioning. One of the most widely used methods for evaluating the sealing capacity of these materials *in vitro* is the study of apical leakage, where the tooth is immersed in a dying solution and quantitative measurements are made of the degree of retrograde penetration observed. Different approaches have been described for accessing the root canal to visualize dye penetration, including longitudinal sectioning with a diamond disc, clearing, and cross-sectional techniques The results of this *in vitro* study suggest that: (a) None of the sealers used completely prevent dye penetration, although leakage in all three groups was small; (b) no significant differences were observed among the sealers tested; and (c) the clearing technique allows more precise determination of dye penetration than the cross-sectional technique.[23]

Smith and Steiman evaluated the apical microleakage of four root canal sealers was performed using a dye leakage/clearing method. Ketac-Endo, Tubliseal (old formula), Tubliseal (new formula), and Roth's 801 cement. Linear dye penetration was determined by dissecting microscope. They concluded that there was no difference between the Tubliseal formulations and the Ketac-Endo showed significantly more leakage than the three zinc oxide-eugenol-based sealers.[24]

Hembree (2000) concluded that A H 26 and Diaket showed less apical microleakage along with all the ZOE formulations.

Gutta flow

Aminsobhani (2010 IEJ) evaluate the coronal microbial leakage in root canals that were either filled by lateral compaction, Gutta Flow or warm vertical compaction and concluded that no statistical difference was found between lateral compaction, Gutta Flow, and warm vertical compaction sealing ability.[23,25]

Endorez urethane based sealer was compared with AH Plus by Kardon *et al*. (2003) assessing the differences in sealing ability by fluid filtration method. Their results indicated that Endorez was not as effective at sealing the apex as AH Plus. Recent study showed that the sealing ability of Endorez was enhanced by using a self-etch adhesive.[23]

Meatseal latest resin root canal sealer. Its self-etch formula hybridizes the dentin wall of the canal to prevent leakage.

Belli et al compared Metaseal with epiphany/Realseal and AH Plus with Gutta-percha and found less leakage with Metaseal.[23]

In 2004 Economides, carried out a comparative study of apical sealing ability of a new resin-based root canal sealer with and without the presence of smear layer. The model used for the measurement of microleakage was a fluid transport model. Result showed that the microleakage values were less when the smear layer was removed.[26]

In 2006, Bodrumlu and Tunga, did an *in vitro* study to access the apical sealing ability of Resilon obturating material. Results showed that the teeth filled with gutta-percha and AH 26 displayed the most apical leakage. The least apical leakage was shown with Resilon.[27]

In 2008, Oddoni *et al*., did a study to compare the coronal and apical leakage of AH Plus with gutta-percha to that of Epiphany with Resilon. Results showed that AH Plus with gutta-percha and Epiphany with Resilon provided the same coronal seal, whereas Epiphany with Resilon provided the best apical seal.[22]

Conclusion

There are no biological absolutes; there are however varying degrees and definitions of success. Successful endodontic therapy is perceived to be the resolution and/or prevention of apical periodontitis or the retention of a functional tooth.

Microleakage is an important cause of failure of treatment. It is essential that due regard be paid to the prevention of such leakage, both during and after root-canal therapy, by paying careful attention to the sealing to the tooth. The use of chemically active, adhesive, root-canal sealers may, in the future, play an important role in minimizing microleakage.

Prevention of microleakage in endodontically treated teeth is most important for patients who rely on the combined expertise and quality care of the dentist/endodontist colleagues. Microleakage is arguably the single most important risk factor for apical periodontitis.

Johnson once wrote "Genius is nothing more than knowing the use of tools, but there must be tools for it to use."

The combination of all innovative technologies has allowed patients to receive the best care available and the most predictable outcomes possible.

That being said, it is the provider that must take this technology and be able use it in the most predictable and efficient way possible. Thus, closing the door on microleakage opens the door to more predictable and successful endodontic outcomes.

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