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REVIEW ARTICLE

Carrier-based Root Canal Filling Materials: A Literature Review

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ABSTRACT

A review of the literature on the use of carrier based obturation materials focusing on Thermafil and Resilon based obturator (RealSeal 1) are presented in this article. The review addressed the history, apical leakage, coronal leakage, biocompatibility, sealing ability and clinical success of Thermafil and RealSeal 1.

Based on the studies gathered, this review concluded that both treatment techniques (Thermafil and RealSeal 1) did not provide excellent apical sealing ability. More research should be done to try to overcome their main drawback, its sealing ability.

Keywords: Thermafil, RealSeal, Resilon, Obturator, Sealing ability.

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INTRODUCTION

Obturation of the prepared radicular space is vital in endodontic therapy to prevent the ingress of bacteria into the cleaned and disinfected root canal space and to prevent the recolonization of bacteria present at the time of root filling. An animal study showed that obturation alone of canals while still infected would result in some reversal of apical periodontitis.[1] Therefore, if our obturation materials and techniques were improved, it might be possible to trap remaining bacteria in the root canal, to stop coronal leakage and the reinfection of a previously disinfected canal. Obturation of the prepared radicular space has been achieved by using a wide variety of materials. Gutta-percha is the most popular and commonly used root canal filling material. Resilon (Resilon Research LLC, Madison, CT, USA), a newer filling material, was introduced in 2004. Resilon is used with a resin sealer. The rationale behind this product is to create a 'mono-block' consisting of a resin sealer that bonds to dentinal tubules as well as to the core material.[2]

Examples for commonly used obturation techniques include cold lateral compaction, warm lateral compaction, warm vertical compaction and carrier based root-filling materials. Thermafil (Dentsply, Tulsa Dental, Tulsa, OK, USA) is a carrier based root-filling technique that utilizes gutta-percha as the filling material. RealSeal 1 (SybronEndo Corp, Orange, CA) is another carrier based root-filling material that has been recently introduced into the market. RealSeal 1 utilizes Resilon as the filling material. According to the manufacturer, RealSeal 1 provides better seal than the conventional gutta-percha carrier based root-filling materials.

The rationale of this review was to improve obturation of the root canal system in three dimensions is advocated to prevent the recolonization of microbes and subsequent failure of endodontic therapy. To the best of our knowledge, no literature has compared the leakage resistance of RealSeal 1 with that of Thermafil using the bacterial leakage model. Furthermore, the ability of RealSeal 1 to adapt to the canal walls in the apical third has not been investigated.

LITERATURE REVIEW

Importance of Obturation

In 1891, Miller[3] described the 'Theory of Focal Infection' as a generalized or localized infection caused by bacteria roving through the bloodstream from a distant focus of infection. With expansion of this theory, in the late 19th and early 20th century, many dentists and physicians recommended extraction of all pulpless and endodontically treated teeth.

In a classic study by Kakehashi et al[4] in 1965, the true significance of bacteria in endodontic disease was shown. They found no pathologic changes occurred in the exposed pulps or periapical tissues in germ-free rats. In conventional rats, pulp exposures led to pulpal necrosis and periapical lesion formation. Thus, bacteria and their byproducts are

the primary cause of pulpal and periradicular pathosis. Therefore, ideally, root canal treatment should sterilize the root canal by eliminating remnants of pulp tissue, bacteria, and microbial toxins from the infected canal system.[5] Elimination of bacteria from the root canal is performed by means of chemomechanical preparation; the mechanical action of instruments and irrigation as well as the antibacterial effects of the irrigants. However, several studies have revealed that after chemomechanical preparation, about 40 to 60% of the root canals are still positive for presence of bacteria.[6,7]

The use of intracanal medication is recommended to further reduce the bacterial load.[8,9] In endodontics, calcium hydroxide [$Ca(OH)_2$] is the best available intracanal medicament to reduce residual microbial flora and is one of the most widely used.[10] Clinical studies showed that the application of $Ca(OH)_2$ decreases the number of canals with detectable bacteria but does not render root canals free of cultivable bacteria.[6,7] In fact, $Ca(OH)_2$ has the ability to exert lethal effects on bacterial cells with a very high concentration of hydroxyl ions when it is in a direct contact.[11] The direct contact is not always possible clinically. In addition, dentin has an inhibitory effect on the antibacterial activity of $Ca(OH)_2$. The diffusibility and low solubility of $Ca(OH)_2$ may find it hard to significantly increase the pH to eradicate bacteria present in tissue remnants, dentinal tubules, biofilms and anatomic variations. The antimicrobial effectiveness is reduced by the buffering ability of dentin and serum which controls pH changes.[12] Also, some microbial species express resistance to $Ca(OH)_2$.[13] Obturation aims to eliminate leakage pathways from the apical and coronal directions and entomb remaining bacteria in the root canal because it is not possible to remove all debris and to sterilize the canal.[14] Katebzadeh et al[1] assessed the role of obturation in healing of apical periodontitis in dogs' teeth. After histological sectioning, they found obturation alone significantly reduced inflammation, compared with the group irrigated with saline and not obturated.

Different Root Canal Filling Materials

Different materials have been used for root canal obturation. Solids, semisolids and pastes have been employed. An ideal root canal obturation material properties are as follows: seals the canal both apically and laterally, minimal setting shrinkage, easily introduced into the canal, nonirritating to the periradicular tissues, impervious to moisture, does not discolor the tooth structure, radiopaque, sterile, antimicrobial, and easily retrievable.[15] Historically, obturation of the canal system has been achieved with gutta-percha and sealer to obtain a tight seal.[16] Gutta-percha has been used in endodontics since the 1860's and it has been the most commonly used filling material. Gutta-percha points are composed of 20% gutta-percha, 66% filler (Zinc Oxide), 11% radiopacifier, and 3% plasticizer (resin or wax).[17] Some of its favorable properties include: biocompatibility, easy placement and removal and radiopacity. However, gutta-percha has no dentinal adhesion. Therefore, it must be used in combination with a sealer cement to fill any voids and gaps between the root dentin and main root-filling material.

An ideal endodontic sealer has the following characteristics: tacky when mixed, make a hermetic seal, radiopaque, nonirritating to periradicular tissues, soluble in common solvents, does not shrink upon setting, does not stain tooth structure, bacteriostatic, set slowly and insoluble in tissue fluids.[18] Four different types of root canal sealers have been introduced in endodontics. For many years, zinc oxide-containing sealers have been the most popular and widely used sealers. Rickerst's was an early zinc oxide-containing sealer. Its major drawback was staining of tooth structure from the silver that was used for radiopacity.[19] Calcium hydroxide-based sealers are the second type. The aim of using calcium hydroxide sealers are stimulation of the periapical tissues in order to promote healing or maintain health and secondly for its antimicrobial effects.[20] The glass ionomer-based sealer has been proposed as an endodontic sealer because of the natural bonding of the glass ionomer cements to radicular dentin.[21] Epoxy-resin based sealers have been used for many years, especially in the form of AH-26 and AH Plus. It has also shown a higher bond strength to dentin than zinc oxide-eugenol, glass ionomer, and calcium hydroxide-based sealer.[22]

RealSeal is a new obturation system introduced in 2004 containing Resilon and a resin-based sealer. Resilon is a thermoplastic synthetic polycaprolactone polymer that contains dimethacrylates, which can bond to methacrylate-based resin sealers like Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA) a resin-based dual-cure root canal sealer. Methacrylate resin–based sealers have attracted significant attention due to its hydrophilic characteristics that enable them to penetrate dentinal tubules,[23] their bond ability to radicular dentin after the use of chelating agents,[24] and their potential bond ability to root-filling materials. According to the manufacturer, the Epiphany sealer sets in approximately 45 minutes by means of chemical cure within the root canal. Light-curing the coronal aspects for 40 seconds create ½ to 1 mm immediate coronal seal. Resilon contains calcium hydroxide, bioactive glass, and radiopaque filler. Like gutta-percha, it has the same handling properties, and may be softened with heat or

dissolved with solvents like chloroform. It is available in master and accessory cones in all ISO (International Standards Organization) different sizes like gutta-percha. It is also available as Resilon pellets which can be used for the backfill in the warm thermoplasticized techniques. The RealSeal system can be utilized with any of the popular gutta-percha obturation techniques: vertical, lateral compaction and continuous wave technique.

Sealing Ability of Obturation Material

Sealing ability and marginal adaptation are two of the most important criteria for an ideal endodontic obturation material.[25] Leakage of the root canal obturation material is the passage of fluids, bacteria and chemical substances between the root canal filling material and the dentinal wall.

Dye penetration is the most frequently used method.[26] Despite its popularity, ease of use and large number of reports, dye leakage method has several limitations. Also, the model is subjective and if the specimen is sectioned, leakage can be measured on the cut surface, and the tooth must be destroyed.[27] Assessment of linear dye penetration can be performed after teeth clearing.[28] The main advantage of the clearing technique is that penetration can be observed in three dimensions, which enables the reading of the maximum extent of dye. This technique does not provide information about the area of dye penetration.[29]

Radioisotope labeling and electrochemical technique are methods used to assess sealing ability of root canal filling materials. They may cause radiation hazard and require sophisticated materials and apparatus which is why they were less frequently employed. The fluid filtration method was introduced and developed by Pashley's group.[30]

Briefly, the root is connected to a tube filled with water that is under pressure. A bubble, inserted in the water, is used to measure the endodontic leakage. In case of an impervious root canal treatment, the bubble does not move despite the pressure. In case of leakage, the bubble moves and its displacement is measured. This method presents several advantages over the common dye penetration method: the samples are not destroyed and it permits the evaluation of the sealing efficiency over time. However, the methods is not standardized, such as the applied pressure, time measurement, the length of the bubble, the diameter of the tube containing the bubble, which can affect the results. Glucose leakage model uses glucose as a tracer. Since the penetrating bacteria or bacterial byproducts may initiate or reactivate an inflammatory process, studies that use a bacterial tracer will provide more biologically significant and clinically relevant information.[31]

Resilon Sealing Ability

Different studies compared the sealing ability of Resilon core and Epiphany sealer to that of gutta-percha AH-26 and AH-plus. Shipper et al[2] examined the resistance to bacterial penetration of Resilon using bacterial leakage model with *Streptococcus mutans* or *Enterococcus faecalis* as the bacterial marker during a 30-day period in a total of 156 single-rooted human teeth. Two filling techniques were used: lateral compaction and continuous wave. Statistical analysis showed all Resilon and Epiphany sealer groups leaked significantly less than all groups in which AH-26 was used as a sealer, in combination with gutta-percha or Resilon. Because the results from this *in vitro* microbial leakage model were so favorable, Shipper et al[32] tested the Resilon system and gutta-percha with sealer in dog models where the histological evaluation can determine the presence/absence of apical periodontitis. Histologic examination showed mild inflammation in 82% of roots filled with gutta-percha and AH-26 sealer and 19% of roots filled with Resilon system. This difference was statistically significant. From this study, Shipper reiterated the 'monoblock' concept in an *in vivo* study with dogs.[32]

The results regarding the better sealing ability of Resilon were in agreement with other studies that compared the microleakage of gutta-percha obturated teeth *vs* Resilon obturated teeth by using a fluid filtration model.[33,34] The Resilon resistance to leakage could be due to the immediate setting of the resin-based sealer on light curing.[34] In contrast to these findings, other research showed better sealing ability of gutta-percha and AH-sealer than Resilon and Epiphany by using fluid filtration method[35] or the bacterial leakage model.[36] The combination of Resilon/Epiphany's inability to produce effective sealing could be explained by the uneven application of primer, uneven application of sealer, inadequate evaporation of the primer solvent.[35,37] Ribeiro et al,[38] discussed some of the factors that might affect the adhesive system of methacrylate resin-based sealers. These included: the presence of oxygen molecules in dentinal tubules that may affect the polymerization of sealer/dentine interface. Tay et al[39] found the weak chemical bond in RealSeal system was between the methacrylate-based sealer and Resilon. This finding reinforces the statement that failure recorded in sealer/dentine interface was related to the sealer and not to the primer application.[39] Other investigations showed similar results between gutta-percha and Resilon in terms of sealing ability[37,40] even after smear layer removal.[41]

Quality of Root Canal Obturation with Resilon

Different techniques can be used to evaluate the quality of endodontic fillings. These techniques include using a microscopy approach, radiographs and the microcomputed tomography. In 2006, Epley et al[42] used a stereomicroscope to evaluate the presence of voids with Epiphany system used with lateral compaction or continuous wave obturation technique at 1, 3 and 5 mm from the apex. Results were compared with gutta-percha techniques. The gutta-percha, lateral compaction method at 3 mm was the only group that demonstrated significantly more voids.[42] In contrast to their finding, Gulsahi et al[43] found no significant difference between Resilon and gutta-percha under stereomicroscope. This could be related to the differences in the size and type of specimens and/or type of instruments used for preparation. In another study, SEM and light microscope showed no significant difference between these filling materials when canals were obturated with continuous wave technique at 2, 4 and 6 mm from the apex in the percentage of core material, sealer, debris or voids.[44] When radiographs were assessed to compare the quality of obturation, there was no significant difference between different materials used; Guttaflow, Resilon/Epiphany and EndoREZ. Furthermore, under stereomicroscope, no significant differences were found in the 2 and 4 mm sections regarding the defect areas in the different sealers.[45] Microcomputed tomography showed that a gap-free or void-free root canal filling was not obtained with neither gutta-percha nor Resilon. However, gutta-percha showed lower percentage of voids and gaps.[46]

Thermafil Sealing Ability

The sealing ability of Thermafil was evaluated in different studies. The majority of these studies compared Thermafil to cold lateral compaction because at that time it was the most accepted and common technique used for obturation.[29] Advantages of the cold lateral technique include its relative ease of use, predictability and controlled placement of materials. Disadvantages include an increased number of voids and sealer pools, less adaptation to canal walls and irregularities and a lack of homogeneity of the gutta-percha mass.[47] Numerous *in vitro* studies have indicated that Thermafil was more effective in restricting apical dye penetration than lateral compaction.[48] One study showed that removing the smear layer significantly reduced the apical dye leakage in teeth obturated with Thermafil.[48]

Leung and Gulabivala[49] found in their study that Thermafil provided a better seal to Indian ink than lateral condensation. The results were statistically significant for canals with curvature greater than 25°, but not for those less than 25°. The author explained this by the performance of cold lateral compaction being compromised by canal curvature, whereas the simplicity of the Thermafil technique overcomes this potential difficulty.[49]

In contrast to these findings, other dye leakage studies found root canals obturated with the Thermafil technique leak more than those obturated with lateral compaction.[50] Differences in results between studies can be attributed to variations in specimens, testing procedures and operator skills.[50]

Other dye leakage studies reported no significant difference in apical sealing ability between Thermafil and lateral condensation technique[51] even in highly curved canals. Another dye leakage study showed no significant correlation between the degree of leakage and apical termination size of the canals obturated with Thermafil.[51]

Bhambhani and Sprechman[52] compared the efficacy of Thermafil obturation with vertical compaction because both use thermoplasticized gutta-percha to obturate root canals. The linear dye penetration measurements showed no statistical significant differences between the amount of leakage in either obturation method.[52] In bacterial leakage study, no significant differences were detected among three different obturation techniques; continuous wave, Thermafil and lateral compaction.[53] In 2001, Pommel et al[54] compared the apical microleakage of roots filled with the system B, lateral compaction, vertical compaction and Thermafil using a fluid filtration system. This study indicated that Thermafil is as effective at sealing the apex as lateral compaction, vertical compaction, and system B when tested immediately. However, after 1 month, lateral compaction presents higher leakage.[54] The authors explained this to be due to the larger amount of sealer in the apical 1 mm when compared with Thermafil. In another study, there was no significant difference in the sealing ability of Thermafil obturators when compared with cold lateral compaction of gutta-percha as long as a sealer was used. Thermafil obturators without a sealer resulted in significantly greater dye penetration when compared with Thermafil with sealer.[29] This observation agrees with a previous dye leakage study.[55] These results indicated that a root-canal sealer is essential although the alpha-phase transformation to beta-phase in Thermafil is associated with shrinkage of thermoplasticized gutta-percha, the presence of sealer can obviously help offset any contraction of the Thermafil gutta-percha mass.[29]

Quality of Root Canal Obturation with Thermafil

Several studies evaluated the adaptation and the contents of Thermafil obturation. In 1993, Juhlin et al[56] evaluated the adaptation of Thermafil components in resin blocks with standardized, simulated, moderately curved canals and found complete encasement of the carrier with gutta-percha

did not occur in any specimen. Another SEM study indicated that the thermoplasticized gutta-percha from Thermafil showed close adaptation to the dentinal walls and replicated the irregularities of the canals better than the lateral compaction. In the same study, it showed that removing the smear layer enhanced the adaptation of Thermafil to dentinal walls, and observed the entry of the thermoplasticized gutta-percha into the tubules.[48]

De-Deus et al[57] found, under light microscope, the highest percentage of gutta-percha filled area in the apical third in the Thermafil group, when compared to system B, or lateral compaction. This result indicates that Thermafil system can reduce the amount of sealer used during obturation. This was in agreement with a previous stereomicroscope study, conducted in 2002, where Gencoglu et al[58] found Thermafil to be superior in terms of core content than that of obturations with system B or lateral condensation. In their study, the gutta-percha and the carrier were calculated together and classified as core fill.[58] In contrast to De-Deus et al[57] findings, another light microscope study found the highest canal filled area in oval shaped canals, at 5 mm from the apex produced by the Thermafil system when compared with cold lateral and system B techniques but the difference was not statistically significant.[26] The difference between the two studies could be due to the variation in methodology; De-Deus et al[57] did not use sealer in their study and measured the gutta-percha filled area only, whereas in his later study he measured the entire filled area (gutta-percha + sealer).

REALSEAL 1

The new generation of the carrier-based root filling material, RealSeal 1, has been introduced. Like the original RealSeal obturation system, RealSeal 1 utilizes Resilon as the filling material. In this case, it coats the outside of the core and is thermoplasticized by a proprietary oven. All of the filling components of the RealSeal 1 obturation system are comprised of compatible resins. As a result, these components will adhere to each other eliminating any gaps.

RealSeal 1 is used with a new self-etching, resin-based sealer (Epiphany SE sealer) (SybronEndo, Crop, Orange, CA). This self-etching component eliminates the primer from the series, simplifying the sealing technique. It allows the removal of the smear layer of the canal dentin so that the sealer can ionically bond to the canal walls. Consequently, the sealer adheres to the dentin, the Resilon adheres to the sealer and the core adheres to the Resilon. The physico-chemical properties of Epiphany SE sealer were evaluated. It has been shown that the setting time, flow, radiopacity, and solubility fulfilled the American National Standard Institute/American Dental Association standards (ANSI/ADA).[59] The self-etch sealer is applied in the manner of traditional sealers. As claimed by the manufacturer that RealSeal 1 creates a homogeneous fill that significantly enhances sealing, overcomes leakage associated with stripping. Also, the radiopacity of the system enhances diagnosis and provides a dense three-dimensional fill.

According to the manufacturer, some of the advantages of RealSeal 1 over conventional carrier-based root filling materials is that the current carrier-based filling materials use gutta-percha and because of the nature of gutta-percha, it cannot be injection molded. Rather, it must be applied to the carrier by dipping. This process can lead to an uneven distribution of gutta-percha on the carrier. When these carriers encounter a constriction in the canal, the gutta-percha coating can be stripped off rather easily. While, the RealSeal 1 obturator is formed and covered with Resilon using injection molding, making a consistent covering of the core. The compatibility of the resin-based Resilon and the resin core material allow adhesion of the Resilon to the core. When the obturator encounters a constriction in the canal, only the surface portion of the Resilon is stripped away. A thin layer of Resilon still remains adhered to the carrier. This thin layer of Resilon is sufficient to allow adhesion of the resin-based sealer to the core. For post space preparation and retreatment purposes, the removal of the Resilon filling material and the core of the RealSeal 1 obturators are relatively easy to accomplish. A post space can be created by using a Touch and Heat or the system B device to remove the Resilon. The remaining Resilon and core can be removed by the use of a post drill or a GatesGlidden drill. For retreatment, solvent will soften both the Resilon and the obturator core in just a few minutes.

DISCUSSION

Both materials, RealSeal 1 and Thermafil, were shown to be nontoxic.[60] Different studies compared the sealing ability of these two different carrier-based filling materials with different methods. With the use of fluid filtration system device, it has been shown that RealSeal 1 has significantly better sealing ability at 24 hours than Thermafil.[61] Another study, conducted on dogs, compared the periapical inflammation and intracanal bacterial penetration of RealSeal 1 and Thermafil after 4-month microbial challenge. After histologic examination, the results showed inflammation in 9% of teeth in the RealSeal1 group, whereas 29% of teeth in the Thermafil group were inflamed. Bacterial penetration was evident in 9% of the RealSeal 1 teeth whereas 70% of the Thermafil teeth showed a similar presence of bacteria within the canal, the difference was

statistically significant. This study concluded that with a dog model RealSeal 1 resists bacterial penetration more effectively than Thermafil.[62] Ordinola-Zapata et al[63] found no significant difference in the percentage of sealer penetration in mandibular mesial root canals filled with the Thermafil or RealSeal 1 systems at the 3 or 5 mm level analyzed by confocal laser scanning microscopy. The same study found the stripping of the plastic core in Thermafil-filled canals was more common compared to RealSeal 1. Also, both techniques showed the ability to completely fill the root canals. Occasionally minor voids with gaps were found in isthmus areas.[63]

CONCLUSION

This review concluded that both treatment techniques (Thermafil and RealSeal 1) did not provide excellent apical sealing ability based on the gathered studies. More research should be done to try to overcome their main drawback, its sealing ability.

ETHICAL STATEMENT

This is a literature review which do not require ethical approval.

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