A review of a resin-based root canal filling material

Cora Hiu-Wan Ko *, BDSc, MDS
Gary Shun-Pan Cheung *, BDS, MDS, PhD, MSc, FRACDS, FHKAM (Dental Surgery), FCDSHK (Endodontics)
Alex Wai-Kwok Chan *, BDS, MDS, MSc, FRACDS, FHKAM (Dental Surgery), FCDSHK (Endodontics)

ABSTRACT In the early 2000s, a new resin-based root canal filling material, so-called Resilon, was developed and marketed with a view to overcoming the limitations of gutta-percha material in achieving an effective seal. In this review article, the properties of Resilon as a root canal filling material are discussed. It seems that Resilon may be a suitable alternative to gutta-percha for root canal obturation. However, both the predictability and reliability of its bonding to dentin (as advertised) still have much room for improvement.

Key words: Dental leakage; Gutta-percha; Root canal filling materials; Root canal obturation

Introduction

The aim of root canal treatment is to eliminate bacteria and their by-products, and to prevent re-contamination of the root canal space. This is achieved by chemomechanical preparation 1, provision of a three-dimensional fill of the root canal system 2 and, finally, placement of a sound coronal restoration 3. Long-term success after treatment is dependent on the development and maintenance of a bacteria-tight seal along the length of the root canal 4.

The first gutta-percha root canal filling material, known as ‘Hill’s stopping’ after its inventor, was patented and introduced into dentistry in 1848 5. Over the years, many techniques have been developed to facilitate a three-dimensional fill using this material. Typically, gutta-percha is used either as a solid cone or plasticized by heat (or by a chemical agent in the past), together with a sealer, to obliterate the internal confines of the root canal system. Nowadays, gutta-percha is the most commonly used material for root canal obturation and has been regarded as the ‘gold standard’ with which new materials or techniques are compared. However, the latter materials fail to provide a predictable seal against prolonged bacterial challenge 4.

Use of resin composite as obturation material

A resinous cone (that handles in a similar manner to gutta-percha), which is capable of adhering to root canal walls (via a dentin-bonding agent) and remains bonded over time to provide an impervious seal, is desirable 6. Such a material could enhance the seal by reducing microleakage from both apical and coronal directions, and provide a barrier to oral bacteria should the coronal restoration be lost or broken. Supposedly, this would contribute to the long-term success of conventional root canal treatment. Few studies have evaluated the potential of using dentin-bonding agents and (traditional) resin composite materials to obturate root canals 7,8. In the past, the working properties of such dentin adhesives and restorative resin systems had problems with radiopacity and retreatability 9. Reasons given for not using such resin composite materials were questionable outcomes, difficult and unpredictable methods of delivery into the root system, and inability to retreat the canal if necessary.

Polycaprolactone as a new obturation material

In the early 2000s, a new resin-based, thermoplastic root canal filling material based on a biodegradable synthetic polyester, called polycaprolactone, was marketed as Resilon (Pentron Clinical Technologies, Wallingford [CT], US). It was claimed to overcome the limitations of gutta-percha and traditional resin-based restorative...
materials used in root canals\textsuperscript{10,11}. The material contained filler particles made of bioactive glass, bismuth oxychloride, and barium sulfate\textsuperscript{10,11}. Apparently, Resilon could bond to dentin by copolymerizing with resin cement via methacrylate-based components in its molecular structure. According to the manufacturer, Resilon has a melting range between 70 and 80°C, which is very similar to gutta-percha\textsuperscript{12}, and a filler content of more than 60% by weight. The material performed, handled, and looked like gutta-percha, and like dental gutta-percha cones it could be used with any cold or warm obturation technique\textsuperscript{10,11}. It could be softened with heat or solvents such as chloroform\textsuperscript{13}, and was highly radiopaque\textsuperscript{14}. When used with a warm technique, its temperature increased less than that of gutta-percha at a distance of 1 to 3 mm from the heat source; the difference being approximately 2°C, though 4 mm away the temperature attained was similar\textsuperscript{12}. In terms of retreatability, Resilon could be removed with an engine-file used in combination with chloroform or heat\textsuperscript{15}, or with Gates-Glidden burs and Hedström or rotary files\textsuperscript{15}. Resilon cones came in International Organization for Standardization sizes with different body tapers, while accessory sizes with pointed tips were available in non-standardized taper. Resilon pellets were also available for use with Obtura II (Obtura/Spartan, Fenton [MO], US) injectable system. Commericially available sealers for Resilon are methacrylate-based. Examples included: Epiphany (Pentron Clinical Technologies, Wallingford [CT], US), RealSeal (SybronEndo, Orange [CA], US), SimpliFill (LightSpeed, San Antonio [TX], US), and InnoEndo (Heraeus-Kulzer, Armonk [NY], US).

The dentin bonding system or sealer for Resilon is called Epiphany. The Epiphany primer (Pentron Clinical Technologies), an aqueous self-etching primer, contains 2-hydroxyethylmethacrylate (HEMA), a sulfonic acid-terminated functional monomer, and a polymerization initiator. The Epiphany Root Canal Sealer (Pentron Clinical Technologies) is a dual-cured, low-viscosity resin composite consisting of a mixture of bisphenol A-diglycidyl dimethacrylate (Bis-GMA), ethoxylated Bis-GMA, urethane dimethacrylate (UDMA), hydrophilic difunctional methacrylates, and filler particles (mixture of calcium hydroxide, barium sulfate, barium glass, and silica)\textsuperscript{11}. The filler constituted more than 50% of the material by weight. Moreover, the material could be cured using a curing light and was thus capable of providing an immediate seal at the canal orifice, so as to achieve on-demand curing. If not light-activated, this resin sealer self-cured in approximately 30 to 60 minutes.

Disinfection of Resilon cones could be carried out in a manner similar to gutta-percha. When contaminated with Enterococcus faecalis or Candida albicans, they could be disinfected effectively with 1% and 5% sodium hypochlorite (NaOCl) for 1 or 5 minutes, or with 2% chlorhexidine for 5 minutes\textsuperscript{16}. Such rapid disinfection could also be achieved using MTAD (Dentsply Tulsa, Tulsa [OK], US)\textsuperscript{17}. However, 5-minute applications of 5.25% NaOCl or 2% chlorhexidine appeared to cause alterations to the surface of Resilon material, such that optimal time for rapid decontamination by disinfectant solutions has yet to be resolved\textsuperscript{18}. Notably, the Epiphany sealer offered no significant antibacterial effect\textsuperscript{19}, in contrast to zinc oxide-eugenol–based or AH26/AH Plus (Dentsply DeTrey, Konstanz, Germany) sealers.

Resilon cones and the Epiphany resin are said to form a ‘mono-block’, i.e. a single block of material that adheres to the dentinal wall\textsuperscript{10,11}. The concept of bonding to the root canal wall is appealing, especially if such adhesion can be achieved along the entire length of the canal. Yet, the purported immediate coronal seal has not been proven.

**Sealing ability of Resilon**

Good adhesion should bring about a predictable seal; however, scientific evidence of the effectiveness of Resilon and Epiphany sealer in sealing the root canal is scarce and inconclusive. On the one hand, using Streptococcus mutans and E. faecalis in a bacterial leakage model, Shipper et al.\textsuperscript{10} showed that after 30 days, root canals filled with Resilon and Epiphany leaked significantly less and more slowly than those with gutta-percha and AH26 sealer. Similar conclusions have been reported with dye leakage tests\textsuperscript{20}, fluid filtration tests\textsuperscript{21}, and electrochemical testing\textsuperscript{22}. In contrast, a bacteriological leakage study has indicated no significant difference in sealing ability between Resilon and gutta-percha\textsuperscript{23}. These contradictory results may be attributed to the various leakage tests used. While detection of bacterial leakage might seem biologically relevant, the inferences could depend on the bacterial species used, and how aseptic conditions were maintained throughout the experiment. Epiphany sealer contains calcium hydroxide fillers, which might affect the bacterial leakage testing due to its potential bactericidal properties. Dye penetration often yields variable results (affected by specimen preparation and the tracer particles), and is also a poor indicator of the clinical treatment outcome\textsuperscript{24}. One study reported a lack of correlation between dye penetration,
fluid filtration and electrochemical assessments. In a study with dogs, after 14 days of contamination of the access cavity with indigenous dental plaque, of the 22 roots treated with gutta-percha and AH26 sealer, 18 (82%) showed mild periapical inflammation, compared with four (19%) of 21 roots treated with Resilon and Epiphany sealer. However there was no mention of any extrusion of material into the periapical tissues, which could very well influence the development of periapical inflammation. Also of clinical importance, calcium hydroxide does not adversely affect the seal achieved with Resilon.

As a root-end filling material, Resilon was reported to be comparable to MTA (Dentsply Tulsa, Tulsa [OK], US), and leaked significantly less than Super-EBA (Bosworth, Skokie [IL], US), when challenged with Streptococcus salivarius. Although the Resilon/Epiphany system may be advantageous with respect to its ability to cure ‘on-demand’, its marginal adaptation and maintenance of the seal in the presence of moisture or blood requires further investigation before its routine use as a root-end filling material.

Spreadable penetration and apical seal

Lateral compaction is probably the most widely taught obturation technique worldwide. It may be carried out with a finger or hand spreaders; any microleakage (apical-to-coronal in direction) generally extends up to a level that the tip of the spreader could reach. Thus, a canal shape that allows the placement of spreader to within 2 mm of the working length, with the master cone (of 0.02 taper) in place, would provide a better apical seal than when the tip of the spreader is more than 2 mm short of the working length. With the introduction of nickel-titanium (NiTi) rotary files that have a greater body taper, the use of master cones involving 0.04 or 0.06 tapers have been proposed. In a recent study, it was shown that with a compaction load of 1.5 kg, a 0.02-tapered Resilon cone allowed the greatest penetration depth (1.1 mm from working length) of a NiTi finger spreader, followed by 0.02-tapered gutta-percha (2.0 mm), 0.04-tapered Resilon (3.8 mm), and 0.04-tapered gutta-percha (5 mm). The inability to obtain spreader penetration to within 2 mm of the apical terminus using gutta-percha or Resilon cones with greater body taper has raised concerns about the quality of the apical seal. On the other hand, the relative importance of a deep spreader penetration versus a matched size for the master cones (of greater taper) has not been reported in the literature.

The interfacial bond strength of Resilon to root dentin

A ‘mono-block’ of material that adheres to the canal wall strengthening the endodontically treated teeth is appealing. A ‘mono-block’ of gutta-percha in the root canal has not been possible, due to lack of chemical union between gutta-percha (a polyisoprene) and various sealers, such as zinc oxide-eugenol, epoxy resin, and glass-ionomer–based sealers. The manufacturer asserts that Resilon bonds chemically to dentin via methacrylate-based resin sealers, though this claim is still under investigation (see below).

When interfacial bond strength and failure of the bond to dentin by the Resilon/Epiphany system was compared with those by gutta-percha and AH Plus sealer, the latter exhibited significantly higher interfacial strength; there being several premature failures for the former. Under an environmental scanning electron microscopy (SEM) examination, the gutta-percha–filled specimens failed exclusively along the gutta-percha/sealer interface, while the Resilon specimens predominantly failed along the sealer/dentin interface with fractured resin tags. These findings agreed with the location of gaps at various interfaces reported by Shipper et al., Tay et al., and Aptekar and Ginnan. Although a dentin hybrid layer can be formed by the Resilon/Epiphany system, regions of interfacial separation still exist.

The Epiphany sealer has been shown to penetrate 6.5 times deeper into dentinal tubules than Tubliseal (Kerr, Orange [CA], US), implying the possibility for a better final sealing ability, though conflicting results in the bond strength of Resilon/Epiphany to dentin have been reported. Yet, others have shown no significant difference, or a lower push-out bond strength for Resilon/Epiphany than gutta-percha/AH Plus. Tay et al. have provided ultrastructural evidence by SEM examination; there being phase separation of the resinous components within the polymer matrix of Resilon, resulting in adhesive failure. Ungor et al. also confirmed the nature of bonding failure to be mainly adhesive. It has been suggested that the amount or method of dimethacrylate incorporation in the Resilon material may not have been optimized for predictable chemical coupling to the methacrylate-based sealer. Notably, the SEM result only demonstrated the interface of the
specimen at one (or several) selected location, and so may not be representative of the scenario along the entire length of the root canal wall.

**Polymerization shrinkage of Resilon**

A major problem associated with bonding a resin material in the root canal is the development of stress in the deep, narrow parts due to polymerization shrinkage. Stress relief by flow of the resin is dependent upon cavity geometry and resin film thickness. A configuration factor, or C-factor, has been defined as the ratio of the bonded to the unbonded surface area. Resin at the unbonded surface can move and flow during polymerization, thereby relieving the shrinkage stresses. The high C-factor is a major obstacle to producing gap-free adhesive fillings in root canals. Polymerization shrinkage stress can exceed the bond strength of the resin to root dentin, resulting in debonding on one side of the filling. This can open a pathway for bacterial leakage. Owing to the slow-curing dynamics of the Epiphany sealer (auto-polymerizes in 45 minutes at room temperature), it is able to flow before completely setting and so allows some stress relief. However, the manufacturer’s instruction to create an immediate coronal seal by way of light curing could cancel out this benefit. Also, the rate of chemical polymerization may be accelerated by heat (as from warm obturation techniques), such that maturing bonds between the self-etching adhesive system and dentin may be disrupted during compaction.

**Setting times of Resilon in relation to microleakage**

Nielsen et al. have shown that AH Plus sets in 24 hours in both anaerobic and aerobic environments, while the Epiphany sealer sets in 30 minutes in an anaerobic environment. Notably, the anaerobic environment was said to simulate a closed root canal system, and an aerobic one simulated the canal orifice and periradicular tissues. With the Epiphany sealer, an uncured layer remains on the surface, when exposed to air for 1 week before it sets completely; when it was covered with phosphate-buffered saline, the surface layer remained unset over the entire experimental (3-week) period. The uncured surface layer, so-called the ‘oxygen inhibition layer’, is attributed to oxygen diffusing from the atmosphere into the resin, thus inhibiting the free radical reaction for polymerization of methacrylate monomers (in the Epiphany sealer). Conceivably, the presence of an initially uncured layer of Epiphany sealer may lead to an increased amount of leakage in the short term. Indeed, root canals filled with Resilon without sealer were reported to leak within 24 hours.

**Degradation and biocompatibility of Resilon**

The biodegradability of the polycaprolactone-based Resilon has been an area of concern. Using field-emission SEM and energy dispersive X-ray analyses, it has been found that hydrolysis of the surface component of Resilon takes place after 20 minutes of immersion in sodium ethoxide, exposing the spherulitic polymer structure and subsurface glass and bismuth oxychloride fillers. The ester bond of polycaprolactone can be cleaved by enzymes present in the saliva or extracellular enzymes from microbes such as *Pseudomonas aeruginosa*, *E faecalis*, and various *Actinomyces* strains.

Materials used in the human body must be biocompatible and not cytotoxic. It has been shown that the cytotoxicity of (cured) Epiphany sealer/Resilon is comparable to that of AH Plus/gutta-percha. When tested with human gingival fibroblasts, Resilon is similar in cytotoxicity to gutta-percha. For the sealer, at 1 and 24 hours Epiphany is less cytotoxic than Grossman's sealer (which contains eugenol), and less cytotoxic at 24 hours but more so at 1 hour than Sealapex (SybronEndo, Orange [CA], US) [which contains calcium hydroxide]. In this respect, freshly mixed Epiphany sealer, primer, and the thinning resin appear comparable to freshly mixed AH Plus. Both 4 and 12 weeks following implantation of AH Plus, EndoREZ (Ultradent Products, South Jordan [UT], US), and Epiphany sealers into the symphys region of the jaws of guinea pigs, there were no or slight inflammatory reactions (after 12 weeks), but moderate-to-severe reactions associated with the alternatives.

**Effect of smear layer and irrigant solution**

A smear layer is produced during root canal instrumentation by translocating and burnishing the superficial components of the dentin wall, regardless of the type of instrument and technique. There has been much debate on the need to remove the smear layer before obturation. The smear layer may serve as an avenue for bacterial microleakage and as a source for growth and activity of viable bacteria, which remain entrapped in dentinal tubules. Such a layer may also prevent or delay the action of any disinfectants on bacteria in that location. Removal of the smear layer is reported to
reduce the extent of coronal leakage, regardless of the gutta-percha technique used. On the other hand, others suggested that the debris plug may block the entry of bacteria into the tubules. The smear layer may interfere with the penetration of root canal sealer (and warm gutta-percha) into the dentinal tubules, or even the adhesion of resin material to dentin. Moreover, because the superficial smear layer tends to break away from the underlying dentin, it must be removed so as to achieve high-strength dentin-bonded resin composites.

Ethylendiaminetetraacetic acid (EDTA) and MTAD (Dentsply Tulsa, Tulsa [OK], US), when used in combination with NaOCl, are able to remove the smear layer. The NaOCl, however, has been shown to adversely affect the polymerization of resin composites. According to the manufacturer of Resilon, the root canals should be flushed with 17% EDTA (or 0.2% chlorhexidine) as a final rinse to remove residual NaOCl. To date, one study has evaluated the effects of irrigants on the bond strength of the Epiphany sealer, and found that water or chlorhexidine as the final rinse leads to a significantly lower bond strength, compared with NaOCl, NaOCl/EDTA or NaOCl/MTAD combinations. The use of EDTA or MTAD did not improve the Epiphany-to-dentin bond.

Fracture resistance of teeth filled with Resilon

Due to a number of reasons, it is widely accepted that endodontically treated teeth are more susceptible to fracture than vital teeth. Reasons include: the cumulative loss of tooth structure from caries, trauma, restorative and endodontic procedures, loss of presso-reception, elevated pain threshold, and possible changes in the physical and mechanical properties of dentin. It has been shown that access cavity preparation, root canal instrumentation and obturation can all cause a 5% reduction in relative cuspal stiffness, which may well lead to crown or crown-root fracture. Resin-based dental materials have been proposed as a means to reinforce an endodontically treated tooth, through bonding to dentin. A few studies have shown that regardless of whether a lateral or vertical compaction technique was used, single-canal teeth obturated with Resilon demonstrate a higher fracture load in vitro than those with gutta-percha. By contrast, similar values for fracture resistance have been reported for single-rooted teeth obturated with either material (Resilon or gutta-percha) using a cold lateral compaction technique. Others have also found no strengthening ability by filling the middle and coronal portions of the canal (of immature roots, the apical 4 mm being filled with MTA) with either Resilon, gutta-percha, or a self-curing composite resin. It has been commented that the cohesive strength and the modulus of elasticity of both Resilon and gutta-percha are too low to provide mechanical reinforcement (to the roots) of endodontically treated teeth. Another possible reason for the controversy may be related to the difference in the selection of specimens. A fully formed, permanent tooth with thick dentinal (root canal) walls has a greater load-bearing capacity than that with immature roots and thin walls. Thus, immature roots fracture more easily in comparison to fully formed permanent teeth, irrespective of the root canal filling material used.

Conclusion

Resilon behaves and handles in a similar way to gutta-percha and may be used as an alternative for root canal obturation. Studies have raised doubts about the effectiveness of the formation of ‘mono-block’ within the root canal system, possibly the most attractive feature of Resilon claimed by the manufacturer. Prevention of leakage has not been demonstrated consistently; at best its performance appeared similar to the use of gutta-percha and sealer. Future investigations may focus on the impact of heat on its constituents and the performance of Resilon and Epiphany sealer, their setting time and degree of polymerization, as well as the periradicular response to extruded material. Clinical data regarding the long-term success of this rather new material are lacking and further research is needed.

References


45. Ko CH. Quantification of microleakage of a resin-based root canal filling material.
canal filling material [dissertation]. Hong Kong: The University of Hong Kong; 2006.