*J Dent Sci* 2010;5(2):47–52

REVIEW ARTICLE

# Resilon: a methacrylate resin-based obturation system

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Received: Jan 14, 2010
Accepted: Apr 26, 2010

**KEY WORDS:**
Resilon/Epiphany;
root canal filling material;
root canal obturation

A resin-based root canal filling material, Resilon/Epiphany was introduced to overcome the limitations of gutta-percha and other sealers. It is claimed that Resilon/Epiphany can enhance the sealing ability by forming a monoblock. Studies related to this material are summarized and discussed in this review article. Different *in vivo* and *in vitro* studies demonstrated that Resilon/Epiphany can be an alternative to gutta-percha and other sealers. However, other studies showed that there is still some room for improvement of the properties of the material in order to achieve quality three-dimensional obturation.

## Introduction

The preliminary objectives of root canal treatment are total debridement of the radicular space, development of a fluid-tight seal at the apical foramen, and total obliteration of the root canal systems.[1] Because of the highly complex anatomy of root canal systems (such as lateral/accessory canals, apical ramifications, isthmuses, and fins), completely disinfecting the root canal,[2] obturating all canal systems and achieving a fluid-impervious seal are challenging. Therefore, the need for new directions in endodontic therapy has been emphasized.

One relatively recent approach to enhance the sealing ability of root fillings comes from the field of obturation materials. Obturation materials and sealers were developed based on dentin adhesion technologies borrowed from restorative dentistry.[3] The introduction of the Resilon/Epiphany obturation system (Pentron Clinical Technologies, Wallingford, CT, USA) has challenged the traditional gutta-percha obturation material.[4,5] The purpose of this review article is to discuss the properties of this new material, various ongoing research results, and future experiments and improvements that seem to be required.

The Epiphany primer (sulfonic acid-terminated functional monomer, 2-hydroxyethyl methacrylate, water, and polymerization initiator) conditions the dentinal surface of root canals, demineralizing it, and exposing the collagen matrix.[6] The Epiphany sealer (bisphenylglycidyl dimethacrylate, ethoxylated bisphenylglycidyl dimethacrylate, urethane dimethacrylate, hydrophilic difunctional methacrylates, calcium hydroxide, barium sulfate, barium glass, bismuth oxychloride, and silica) bonds to both the root dentin and Resilon cones (polycaprolactone, bioactive glass, bismuth oxychloride, and barium sulfate) to form a single unit, termed a "monoblock".[7] The material is clinically used exactly like gutta-percha in that it can be applied with warm and cold obturation techniques.[4,6]

The first generation of hydrophilic methacrylate resin-based material (Hydron; Hydron Technologies,

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Pompano Beach, FL, USA) was designed for *en masse* root filling.[8] The second generation (e.g., EndoREZ; Ultradent, South Jordan, UT, USA) uses non-acidic hydrophilic resin monomers after removal of the smear layer from root canal walls.[9] The third generation (e.g., RealSeal by SybronEndo, Orange, CA, USA; Epiphany by Pentron Clinical Technologies, Wallingford, CT, USA) includes a self-etching primer and sealer.[10,11] The fourth generation (e.g., MetaSEAL by Parkell, Farmington, NY, USA; RealSeal SE by SybronEndo; and Epiphany SE by Pentron Clinical Technologies) consists of a self-etching moderately-filled flowable composite with acidic monomers. The self-etching sealer reduces the technique sensitivity, especially in the apical third where primer application might not be adequate.[12] The Resilon obturation system is now available with a Resilon core, primer and sealer, a Resilon core and self-etching sealer, and a carrier-based delivery system.[13]

## Sealing ability

One of the requirements for successful root canal treatment is to achieve and maintain a tight seal, chemically and/or mechanically, along the root canal system.[14] A tight seal should prevent the ingress of bacteria and their by-products into periradicular tissues or entomb the remaining microorganisms and hence prevent or heal apical periodontitis.[15]

Microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material.[16] Microgaps may be caused during placement because of polymerization shrinkage, an air bubble or poor adhesion and wetting, or may develop with time because of thermal stresses, occlusal loading or water sorption (water absorption and water adsorption simultaneously taking place).[17]

Studies have compared Resilon/Epiphany with gutta-percha and other sealers using dye leakage, a fluid filtration test, and a bacterial leakage test. Examination of 105 sectioned teeth under a dissecting and scanning electron microscope (SEM) for assessment of dye penetration, sealing and bonding showed that compared with gutta-percha, Resilon resulted in less microleakage at 10 days, and 1 and 3 months.[18] Tunga and Bodrumlu[19] and Stratton et al.,[20] who also used a fluid-transport method, concluded that Resilon showed less leakage than gutta-percha. In contrast, other studies[21,22] have demonstrated that there was no difference in fluid movement of Resilon/Epiphany compared with gutta-percha/AH Plus (Dentsply DeTrey GmbH, Konstanz, Germany) after obturation, but Resilon/Epiphany showed significantly more fluid movement after 14 months[11] and 16 months[23] of water storage. However, these long-term studies under water storage neither simulated the actual oral environment nor took into consideration other factors like thermal changes and load during mastication that might cause gap formation at the dentin–resin interface and lead to increased microleakage.[24] The bacterial leakage test done by Shipper et al.[4] using *Streptococcus mutans* and *Enterococcus faecalis* through gutta-percha/Epiphany, gutta-percha/AH Plus, and Resilon/Epiphany during a 30-day period revealed significantly less coronal leakage in the Resilon group. An *in vivo* study done by the same authors on dog teeth by inoculating dental plaque coronally showed that the Resilon obturation system was associated with less periapical inflammation (19%) compared with gutta-percha (88%), which may have been because of Resilon's superior resistance to the coronal microleakage.[5] However, there was no significant difference between gutta-percha/AH Plus and Resilon/Epiphany in studies done by Baumgartner et al.[25] and Pitout et al.[26]

The effect of an intracanal medicament on the sealing ability of Resilon/Epiphany was investigated by Wang et al.[27] and Pasqualini et al.[28] There was no apparent difference in microbial leakage in groups with and without calcium hydroxide intracanal medication, although the remaining intracanal medicament calcium hydroxide, which has a high pH value, might neutralize the acidic primer of the Resilon/Epiphany system.

Like intracanal medicaments, irrigation solutions may similarly affect microleakage. The widely used sodium hypochlorite irrigation solution is a strong oxidizing agent and leaves behind an oxygen-rich layer on the root dentin surface. This oxygen layer inhibits free radical polymerization which may result in reduced bond strength and increased microleakage.[29] Reducing agents, like ascorbic acid, citric acid and sodium ascorbate,[30] can be used to reverse the effects of sodium hypochlorite. Final irrigation with EDTA (ethylenediaminetetraacetic acid) can also be used as recommended by the manufacturer. A final rinse with chlorhexidine may arrest degradation of the hybrid layer by inhibiting host-derived matrix metalloproteinases that are present in the dentin and released slowly over time.[31,32] In one study, after root canal preparation and removal of the smear layer with 17% EDTA, the teeth were irrigated with 5.25% sodium hypochlorite, 0.012% chlorhexidine or 2% chlorhexidine for 10 minutes before obturation with Resilon/Epiphany, or gutta-percha/AH Plus. Although the Resilon group was superior, there was no significant difference among the irrigation groups.[20] In that study, however, the teeth were stored for only 20 days, and the long-term effect of the irrigation solution was unclear.

The use of any alcohol is not recommended for drying the canals prior to obturation with resin-based

materials. Wet root dentin is required for the effective bonding of the adhesive. The Resilon/Epiphany system showed less coronal dye penetration when the root canals were dried with multiple paper points and a Luer vacuum adapter (Ultradent Products Inc., South Jordon, UT, USA) plus paper points compared with 95% ethanol drying and wet conditions.[9] However, one of our own studies using micro-Raman spectroscopy showed that the root canals dried with supplemental use of 95% ethanol favored the degree of conversion of RealSeal SE, compared with the group dried with paper points.[33] Further research is required to correlate the degree of conversion with the sealing ability of this material.

In the above-mentioned studies, methods employed like the storage medium, duration, temperature, cleaning and shaping techniques, irrigants, obturation technique, aging, tracer type, and leakage tests widely varied; therefore, they cannot be directly compared. In addition, it was reported that there is a poor co-relationship between these leakage tests.[34] Despite the shortcomings of the *in vitro* leakage tests, they remain useful as an initial screening of new materials and techniques for canal obturation.

Nanoleakage was originally used to describe micro-porosities within hybrid layers that allow silver nitrate penetration to occur in the absence of gap formation between the resin composite and hybrid layer.[35] Effective dentin bonding depends upon the formation of a hybrid layer that is optimally infiltrated with adhesive resins. Incomplete resin penetration in the hybrid layer permits nanoleakage to occur. Transmission electronic microscopy revealed the presence of silver penetration along the sealer–hybrid layer interface when the canals were obturated with Resilon/Epiphany,[36] EndoREZ, RealSeal SE or MetaSEAL.[37] The clinical significance of nanoleakage is unclear, as the spaces are submicron in dimensions and hence too small to permit bacterial entry. However, water could easily diffuse through these spaces, which could change their dimensions under occlusal function. Increased porosity might occur via a nanoleakage pathway at the bonded interface over time, which would lead to the breakdown of the bond and subsequent failure of the filling material.[38]

## Bond strength

According to the manufacturer, the Resilon polycaprolactone polymer core contains a blend of dimethacrylates that bonds with the methacrylate-based sealer,[39] which in turn bonds with the root dentin, forming a monoblock that may improve the seal and strengthen the endodontically treated tooth.[7]

A bond strength test is a frequently used method to evaluate the mechanical properties of adhesive materials. Factors that can affect the *in vitro* bond strength of these materials to human dentin include the curing method, substrate,[40] the method of dentin conditioning,[41] moisture,[9] and irrigants.[42]

Various *in vitro* studies were done to evaluate the bond strength of methacrylate-based sealers. Some of those studies demonstrated that the gutta-percha/AH Plus system had significantly higher bond strength compared with the Resilon/Epiphany system[43–48] and Resilon/Epiphany SE.[43] In contrast, other authors showed higher bond strengths for Resilon/Epiphany.[49,50]

Concerning failure modes, gutta-percha failed along the gutta-percha/sealer interface, while Resilon predominantly failed along the sealer/dentin interface with recognizable, fractured resin tags. Detachment of Resilon from the Epiphany sealer was also observed in some specimens, which challenges the concept that it strengthens endodontically treated teeth.[45] Wilkinson et al.[51] demonstrated that Resilon and gutta-percha could not resist fracture of simulated immature teeth. But in another study, obturation of roots with resin-based obturation materials (Resilon and EndoREZ) increased the resistance of teeth to vertical root fracture compared with gutta-percha/zinc-oxide eugenol, and gutta-percha/GuttaFlow.[52] The modulus of elasticity of Resilon should be equal to that of the dentin (15,000–18,000 MPa) to reinforce and strengthen it. But the modulus of elasticity and cohesive strength of Resilon are much lower than those of dentin. As a result, the polymer chains slide over each other under stress and, therefore, the material flows in a condition of stress instead of resisting the stress.[53] Hence, the concept of root strengthening with Resilon is controversial.

## Biocompatibility

Besides creating a proper seal, an obturation material should be nonmutagenic, noncarcinogenic,[54] and nonirritating to periradicular tissues,[55] and should not provoke an immune response.[56] A cytotoxicity evaluation of the Active GP mono-cone obturation system (Brasseler USA, Savannah, GA, USA), gutta-percha, and Resilon cones *in vitro* showed better biocompatibility of Resilon with significantly more viable cells.[57] Human gingival fibroblast cultures revealed that Resilon had lower cytotoxicity, while Epiphany was more cytotoxic than conventional materials.[58] Similarly, another study showed the cytotoxicity of RealSeal to MG63 cells.[59]

However, an *in vivo* study performed on guinea pigs at 4 and 12 weeks showed that Epiphany was compatible with bone formation and showed no inflammation to only slight inflammation, while

moderate to severe levels of inflammation were shown with AH Plus and EndoREZ.[60] Likewise, studies with Epiphany implanted into four different regions of the dorsum of rat tissue exhibited acceptable biocompatibility.[61–63] Histopathologic examinations revealed that Resilon cones and gutta-percha had similar biocompatibility in terms of the presence of inflammation, predominant cell types, and the thickness of fibrous connective tissue over a 60-day period.[64]

During root canal obturation, the sealer is extruded beyond the root canal system[65] into the periradicular tissues. One study showed that a layer of uncured Resilon sealer remained on the surface when it was allowed to set in simulated periapical fluid.[66] The effects of uncured sealer on periradicular tissues are unknown. Further research is required to evaluate the biocompatibility of the Resilon obturation system and the effects of extruded material on periapical tissues.

## Degradation

Resins are prone to hydrolysis by enzymes, mechanical loading, and wear. The degradation products and their effects on oral tissues are of prime concern.[67] Resilon showed exposure of glass-filler particles following surface dissolution of the polymer matrix by a gravimetric analysis and SEM, creating a rough surface topography after incubation in lipase PS (from *Burkholderia cepacia;* Amano Enzyme Inc., Nagoya, Japan) or cholesterol esterase (from *Pseudomonas* species; Amano Enzyme Inc.) for 96 hours.[68] Similarly, the presence of spherical polymer droplets that appeared deformed, pitted or much reduced in dimensions was seen with Resilon after enzymatic hydrolysis. Rates of hydrolysis of Resilon by lipase PS and cholesterol esterase were much faster than those of polycaprolactone at a 1× or even 4× enzyme concentration.[69] Field-emission SEM and energy dispersive spectrometric analyses showed that the surface resinous component of Resilon was hydrolyzed after 20 minutes of sodium ethoxide immersion, exposing the spherulitic polymer structure and subsurface glass and bismuth oxychloride fillers. More-severe erosion occurred after 60 minutes of sodium ethoxide treatment, while gutta-percha was unaffected.[70]

Furthermore, gutta-percha exhibited minimal surface changes after 4 months of incubation in wet dental sludge, while polycaprolactone and Resilon exhibited severe surface pitting and erosion. In the latter, disappearance of the polymer matrix was accompanied by exposure of mineral and bioactive glass fillers. Bacteria and hyphae-like structures were present on the Resilon surfaces.[71]

These *in vitro* studies suggest that Resilon degrades with time. It would be very interesting to investigate the effects of oral fluids on Resilon/Epiphany degradation. However, the effect of these fluids and bacterial products inside a root canal system is questionable and may be analyzed by high-performance liquid chromatography. It is important that a material be non-biodegradable and maintain the seal over time. Therefore, more studies regarding this aspect are necessary.

## Efficacy of retreatment

Endodontic success rates range from 53% to 94%.[72] Nonsurgical retreatment may be necessary if the patient does not respond to the initial treatment or in cases of recurrence of signs and symptoms. Therefore, obturation materials must be easily removed for retreatment purposes.

Resilon/Epiphany can easily be removed with the use of solvents, hand and rotary instruments, and application of heat. The Resilon/Epiphany system showed less retreatment efficacy with respect to time and cleanliness than the gutta-percha/AH Plus sealer, with or without chloroform.[73] Another study revealed that Resilon/Epiphany required a significantly longer working period when K3 rotary instruments (SybronEndo, Orange, CA, USA) were used for its removal in simulated curved root canals, and the working time was reduced after heat-softening with System B (SybronEndo).[74]

Somma et al.[75] compared the cleaning efficacy of Mtwo R (Sweden & Martina, Padova, Italy) and ProTaper (Dentsply-Maillefer, Ballaigues, Switzerland) retreatment files and a Hedstrom manual technique for removing three different filling materials, including gutta-percha, Resilon and EndoREZ, during retreatment with optical stereomicroscopy and SEM. The Mtwo R and ProTaper retreatment files, and Resilon filling material had positive impacts on reducing the time for retreatment. Cleaner canal walls were observed for EndoREZ-filled teeth by optical stereomicroscopy, whereas Resilon filling material and both nickel-titanium rotary techniques resulted in less-clean canal walls according to the SEM analysis.

In one of our own studies, canals obturated with the Resilon system were divided into three groups: Group 1 was the original Resilon obturation; Group 2 underwent reinstrumentation with a K-file (Dentsply-Maillefer) and chloroform, followed by refilling with Resilon; and Group 3 underwent instrumentation with ProFile 0.04 taper nickel-titanium rotary instruments (Dentsply-Maillefer) and chloroform, followed by refilling with Resilon, and was evaluated by a leakage test and environmental SEM. All groups showed time-dependent increases in glucose leakage with

no significant difference among them. An environmental SEM study confirmed Resilon tags in all groups with new resin tags in Groups 2 and 3. Furthermore, the presence of old resin tags indicated that the material could not completely be removed.[76]

## Conclusion

Resilon, with the adhesive concept of bonding to root dentin, can be used as an alternative to gutta-percha. Studies have shown that the material still lacks the required properties of an ideal root canal-filling material. Optimal bonding to root dentin is a challenge because of the heterogeneous composition of dentin and anatomical complexity. Taking this into consideration, it is necessary to improve the mechanical and chemical properties of the material. Long-term *in vitro* and *in vivo* studies should be done to evaluate the success rate of endodontically treated teeth using the Resilon obturation system.

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