Resin based root canal sealer combined with self-etching bonding agent

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ABSTRACT

Background: Successful root canal therapy requires chemomechanical preparation, and then a complete obturation of the root canal system with non-irritating biomaterials. One of the major causes of root canal treatment failures is the incomplete sealing of the root canal and shortcomings in coronal restoration, confirming the necessity of using materials capable of forming a bacteria-proof seal between the root canal system and both the periradicular tissues and the oral cavity. Purpose: The objective of this article is to provide information about methacrylate-based resin sealers (MBRS) on which practitioners can base their decision to consider changing established techniques and embrace a new one. Reviews: Particularly the use of dentin bonding agents in combination with gutta-percha cones and a resin-based sealer and the adhesion of composite resins to dentin is known to be better. The bonding agent forms a micromechanical interlock between dentin collagen and resin by forming a hybrid layer. Since the self etching materials have higher pH values than the acids used with etch-and-rinse adhesive system, and the self etching materials are not rinsed away but remain in situ, the smear layer is incorporated in the bonding layers. Conclusion: It can be concluded that the most recently introduced self-adhesive type bondable root canal sealers are also associated with the additional benefits reduced application steps and overall improvements in their user friendliness. Accordingly, the objectives of this review were to clarify the behavior of these sealers and to identify, if possible, evidence-based support on the merits of their clinical use.

Key words: Self-etching bonding agents, resin based sealers

INTRODUCTION

The concept of resin bonding in dentistry was introduced in the mid-1950s by Buonocore, who advocated the use of an acid to demineralize enamel. Skepticism slowly gave way to general acceptance. However, bonding materials and techniques have completely changed over the course of 50 years. During the initial development only hydrophobic resins were available; these have been replaced by hydrophilic resins over time. Furthermore, about 30 years of research resulted in a change from using 85% phosphoric acid liquid for 60 seconds to etch enamel to 35% phosphoric acid gels for 15 seconds to etch dentin and enamel. Although early attempts were strictly focused on preventive and restorative dentistry, it was only a matter of time before orthodontics and then endodontics embraced this concept. Usually, when new materials and techniques are introduced, there is an initial reluctance on the part of practitioners...
to abandon trusted and proven methods until evidence that is sufficiently convincing to change established techniques is generated. 1

The objective of this article is to provide information about methacrylate-based resin sealers (MBRS) on which practitioners can base their decision to consider changing established techniques and embrace a new one. This decision cannot be made by presenting empiric data, but by offering an analysis of scientific evidence from ex vivo and in vivo research. Based on their successful long-track record, gutta-percha and zinc oxide, eugenol, and other conventional sealers, have served as the gold standard for comparison .

### Methacrylate resin-based sealers

To date, four generations of methacrylate resin-based sealers have been introduced. The first generation Hydron (Hydron Technologies, Inc, Pompano Beach, FL) appeared in the mid-1970s when scientific foundations behind dentin bonding were at their infancy stage of development. The use of poly[2-hydroxyethyl methacrylate] (poly[HEMA]) as the major ingredient rendered the sealer very hydrophilic. Hydron was designed to be injected into a root canal and to be polymerized in situ for en masse root filling. It was reported to be easy to use because of its injectability, non-irritating, highly adaptable to the canal walls, nonsupportive of bacterial growth, and able to be calcified in the event of inadvertent extrusion of the sealer into the periapical regions.2 However, the sealer came to a disastrous end and became obsolete in the 1980s because discrepancies between the manufacturer’s claims and laboratory/clinical findings on its physical/clinical properties and biocompatibility became apparent soon after its commercialization. The sealer caused severe inflammatory reaction, absorption of the material, severe leakage, as well as water sorption and swelling.2

The second generation of bondable sealer is nonetching and hydrophilic in nature and does not require the adjunctive use of a dentin adhesive.3 It is designed to flow into accessory canals and dentinal tubules to facilitate resin tag formation for retention and seal after smear layer removal with NaOCl and ethylenediaminetetraacetic acid (EDTA).4 EndoREZ (Ultradent Products Inc, South Jordan, UT) is a dualcured radiopaque hydrophilic methacrylate sealer that might be used in the wet environment of the root canal system and is very effective in penetrating dentinal tubules and adapting closely to the canal walls (Fig. 1A and B).5

Although EndoREZ is recommended for use with either a conventional gutta-percha cone or with specific EndoREZ points (resin-coated gutta-percha) (Fig. 1C and D), low bond strength to the dentinal wall was reported with conventional uncoated gutta-percha. To facilitate rapid cure of EndoREZ, an accelerator that is compatible with EndoREZ has recently become available.5

To simplify bonding procedures, new generations of self-etching (third generation) and self-adhesive (fourth generation) luting resin composites have been introduced to restorative dentistry during the last 5 years. Similar generations of root canal sealers became commercially available shortly after the introduction of those luting resin composite systems. The third generation self-etching sealers contain a self-etching primer and a dual-cured resin composite root canal sealer.
FibreFill R.C.S. root canal sealant (Pentron Clinical Technologies, Wallingford, CT) is an example of a third generation methacrylate resin–based sealer that is designed for filling canals with fiberreinforced obturators that are attached to thermoplastic root filling material tip. The resin sealer is used in combination with a self-cured, self-etching primer system (Fibrefill Primer A and B). Bonding between adhesive systems and dentin depends on the penetration of monomers into the conditioned dentin surface to create micromechanical interlocking between the dentin collagen and resin, forming a hybrid layer. FibreFill R.C.S. is reported to have good sealing and adhesive properties to radicular dentin.6

Another third generation methacrylate resin–based sealer that incorporates the use of self-etching primers became commercially available with the introduction of Resilon (Resilon Research LLC, Madison, CT), a dimethacrylate-containing polycaprolactone-based thermoplastic root filling material.7 For the Epiphany (Pentron Clinical Technologies), RealSeal (SybronEndo, Orange, CA), Resinate (Obtura Spartan Corp, Fenton, MO), and Smart (Discus Dental, Culver City, CA) systems, the self-etching primers are further reduced from a 2-bottle system to a single-bottle system.

The fourth generation methacrylate resin–based sealers (eg, Meta-SEAL, Parkell Inc; RealSeal SE, SybronEndo) are functionally analogous to a similar class of recently introduced self-adhesive resin luting composites in that they have further eliminated the separate etching/bonding step.8 Acidic resin monomers that are originally present in dentin adhesive primers are now incorporated into the resin-based sealer/composite to render them self-adhesive to dentin substrates. The combination of an etchant, a primer, and a sealer into an all-in-one selfetching, self-adhesive sealer is advantageous in that it reduces the application time as well as errors that might occur during each bonding step. MetaSEAL is the first commercially available fourth generation selfadhesive dual-cured sealer. The inclusion of an acidic resin monomer, 4-methacyryloyloxyethyl trimellitate anhydride (4-META), makes the sealer self-etching, hydrophilic, and promotes monomer diffusion into the underlying intact dentin to produce a hybrid layer after polymerization. The sealer purportedly bonds to thermoplastic rooffilling materials as well as radicular dentin via the creation of hybrid layers in both substrates. MetaSEAL is also marketed as Hybrid Bond SEAL (Sun Medical Co Ltd, Shiga, Japan) in Japan and had been reported to produce similar or slightly inferior sealing properties as conventional nonbonding epoxy resin–based sealers.9,10

RealSeal SE is the simplified dual-cured version of RealSeal and uses a polymerizable methacrylate carboxylic acid anhydride (ie, 4-META) as the acidic resin monomer. It might be used with Resilon cones or pellets by using cold lateral or warm vertical techniques or with the more recently introduced RealSeal 1 (SybronEndo), a carrier-based Resilon obturator system.11

DISCUSSION

Several early publications (2001 and 2003) have reported on the biocompatibility and adhesiveness of EndoREZ. Since then numerous publications have appeared, testing different Methacrylate Based Resin Sealers (MBRS) formulations and using a variety of techniques.1

Although root canal sealers are intended to be contained only within the canal space, they might be extruded through the apical constriction or other avenues of communication with the periodontal ligament space during placement. The tissue response to these materials might influence the final outcome of root canal treatment. Contact of extruded sealers might result in irritation of the periradicular tissues and delayed wound healing. Thus, the biocompatibility of root canal sealers is critical to the success of root canal treatment.12

One of the requirements of any dental material for use in humans is that it should be biocompatible. Numerous investigators have conducted cytotoxicity studies ex vivo using cell cultures and in vivo in laboratory animals. The results between investigators are contradictory. Huang and colleagues showed that the elution compounds from MBRS, zinc oxide-eugenol and calcium hydroxide-based sealers were cytotoxic to primary human periodontal ligament cultures and V79 cells, with calcium hydroxide being the least toxic. Huang and co-workers, reported that the highest level of DNA damage was induced by epoxy resin–based sealers, in this case Topseal (Dentsply, Konstanz, Switzerland), AH-26, and AH Plus. Koulaouzidou and colleagues reported similar results. AH-26 had a severe cytotoxic effect, whereas Topseal and AH Plus had markedly lower effects. These findings are surprising as the basic formulation of AH-26 and Topseal is the same. Bouillaguet and colleagues, reported that: “Most
materials pose significant cytotoxic risks and that cytotoxicity generally decreased with time. At 72 hours, GuttaFlow became significantly less toxic than AH Plus, Epiphany sealer, and Resilon. Other investigators, such as Key and colleagues found Epiphany to be less toxic than Grossman’s sealer. However, Epiphany was more cytotoxic than Sealapex after 1 hour, but less after 24 hours. Epiphany was more cytotoxic than conventional materials. In a more recent publication similar findings were reported. According to Lodiene and colleagues the multi-methacrylate-based resin (Epiphany) root canal sealer was significantly more toxic to L-929 cells than the silicone-based RoekoSeal and the single methacrylate-based EndoREZ root canal sealers. AH Plus showed intermediate toxicity.

The early studies on which the launch of EndoREZ was based were conducted by Louw and colleagues and Bécé and Pameijer who reported that EndoREZ was mildly irritating, but within acceptable standards (1.5 is the acceptable limit). Further evidence of biocompatibility was published by Zmener and Zmener and colleagues. In other related studies (Pameijer, 2002, unpublished data), EndoREZ and Epiphany/Resilon reacted more favorably than the control AH Plus. Preoperative and postoperative radiographs were made and root canal treatment was performed according to a standardized protocol using a rubber dam in subhuman primates. Histologic observations were made at various time periods: 30 days to determine an early reaction and from 3 months to 6 months posttreatment for long-term reactions. The results can be summarized as follows.

Leakage continues to be a major reason for failure in root canal therapy. Although the clinical relevance of in vitro leakage studies has been severely challenged, these studies constitute a significant part of the current literature on methacrylate resin–based sealers and cannot be ignored in a review article, particularly in view of the scarcity of evidence-based clinical outcome studies on this topic. Ideally, a root canal filling material should provide a barrier that prevents bacterial ingress from the oral cavity. The Resilon/Epiphany system is reported to establish an immediate coronal seal after lightcuring of the dual-cured sealer at the canal orifices. An immediate coronal seal is clinically advantageous because there are situations in which filled root canals might be exposed to the oral environment and subject to bacterial recontamination. Indeed, Resilon/Epiphany sealer group leaked significantly less than all groups in which AH 26 was used as a sealer for gutta-percha or Resilon. Both EndoREZ/resin-coated gutta-percha and Epiphany/Resilon were found to provide better coronal seal when the respective sealer was used on moist canal wall dentin when compared with the use of a ZOE-based sealer/gutta-percha. However, these findings are in contrast with the results that demonstrated the Resilon/Epiphany system exhibited more leakage than the use of a glass ionomer intraorifice barrier and was not better than gutta-percha/conventional sealers in preventing coronal leakage. It is known that polymers degrade over time through physical and chemical processes.

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**Figure 2.** A pie chart summarizing the results of in vitro studies that compared the extent of leakage between teeth that were filled with methacrylate resin–based sealers versus conventional nonbonding sealers.

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**Figure 3.** At 1st post treatment, the endodontic radiograph of 4 central incisors shows extrusion of sealer (intentional into the periapical tissues.)
In one of the first published leakage tests using India ink, Zmener and Banegas reported no statistically significant difference between EndoREZ and AH Plus. Orucoglu and colleagues, using the fluid filtration method, reported that Diaket with cold lateral condensation leaked less apically than EndoREZ and AH Plus. However, others reported that AH Plus leaked less than EndoREZ and AH-26 using a single cone technique. Compared with zinc oxide-eugenol, MBRS was found to be more effective in sealing. These investigators also used the fluid filtration method. Using similar techniques, it was found that the apical seal of Epiphany and Resilon was not different from AH Plus and gutta-percha, AH Plus and Resilon, and Epiphany and gutta-percha. In contrast, using a fluid-transport method, Tunga and Bodrumlu concluded that Epiphany and Resilon leaked significantly less (P<.05) than gutta-percha and AH-26. Others reached a similar conclusion when comparing Resilon and gutta-percha and AH Plus, in bacterial leakage tests; Epiphany and Resilon were superior to gutta-percha and various other sealers. Pitout and colleagues also used a bacterial leakage test and a dye penetration method and Biggs and colleagues did not observe a difference between Resilon and gutta-percha. Several investigators have used the dye penetration technique to demonstrate that MBRSs are superior or inferior to conventional materials. One explanation for the difference in results between the various MBRS materials can most likely be attributed to the presence or absence of moisture in the root canal at the time of obturation.15

However, the extent of dye penetration may be related to the clinical outcome. The investigators concluded that clinically placed root canal fillings do not provide an apical seal that prevents fluid penetration and therefore the outcome of treatment cannot be predicted based on the results of apical dye leakage studies. In 1993 Wu and Wesselink reviewed the shortcomings of various tests reported in the literature. However, dye leakage studies may be useful to determine the performance of a new material or technique by conducting comparative studies with existing systems. An electrochemical technique that seems to be sensitive and has generated findings that correlate with bacterial leakage tests, has been published by von Fraunhofer and colleagues. Figure 4 illustrates a comparison between resin sealers and conventional sealers.1

Independent of the technique used (fluid filtration or bacterial leakage test or other tests), there is no general agreement on whether there is reduced or more leakage when using MBRS. In addition ex vivo tests frequently do not correlate with clinical performance.1

The entrepreneurial concept of creating a root canal monoblock to achieve a total bond and hence a total seal of the canal space has been hampered by the lack of chemical union between the polyisopren component of gutta-percha and methacrylate-based resins. To circumvent this

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**Figure 4.** Histologic reaction of an experimental sealer (black) extruded into periapical tissues. The white space was occupied by the Resilon point and disappeared during processing for histology. Ingrowth of connective tissue into apical root space adjacent to the point can be observed. Despite the presence of numerous sealer particles beyond the apex, no inflammatory cells were present (hematoxylin and eosin stain, original magnification x64).1

**Figure 5.** At 113 days post endodontic treatment, the sealer (dark brown) is surrounded by a fibrous capsule in the periodontal ligament space. No inflammatory reaction is present as a result of the extruded material, point, and sealer (hematoxylin and eosin stain, original magnification x200).1
problem, several strategies have been used. The first commercialized strategy was introduced by coating gutta-percha cones with a polybutadiene-diisocyanate-methacrylate adhesive. This proprietary adhesive resin includes a hydrophobic portion that is chemically compatible with the hydrophobic polyisoprene substrate and a hydrophilic portion that is chemically compatible with a hydrophilic methacrylate resin. With the use of this adhesive resin coating, a strong chemical union is achieved between the gutta-percha and the methacrylate resin–based sealer. This thermoplastic resin-coated gutta-percha cone is recommended for use with the EndoREZ system.¹⁶

The fourth generation self-adhesive type root canal sealers are still relatively new, and detailed information on their adhesive properties to root filling materials is limited or lacking. For the 4-META containing sealer MetaSEAL, a recent report identified a hybrid layer-like structure along the gutta-percha–sealer interface. However, no data are currently available on the adhesive strength of MetaSEAL to gutta-percha via this hybrid layer-like interface.¹⁷ Taken together, these data suggest that the chemical coupling between contemporary methacrylate resin–based sealers to root filling materials is generally weak or insufficiently optimized. In view of the extremely high C-factor encountered in long, narrow root canals, it is doubtful whether the core material–sealer bond is capable of resisting polymerization shrinkage stresses that develop during the setting of the resin sealer to permit the realization of the goal of creating a monoblock in the root canal system.¹⁷,¹⁸

The combined use of self-etching or self-adhesive methacrylate resin–based sealers and bondable root filling materials would increase the fracture resistance of filled canals. This hypothesis was tested by Teixeira et al. They showed that roots filled with Resilon/Epiphany exhibited significantly higher fracture load values than those filled with gutta-percha/AH 26 when the specimens were subjected to vertical loading forces. This finding was supported by other studies that demonstrated that roots filled with methacrylate resin–based sealers exhibited higher resistance to fracture than those filled with gutta-percha and sealers.

The results of those studies satisfying the 2 aforementioned criteria are represented graphically in Figure 6.

Currently available methacrylate resin–based sealers and their recommended adhesive procedures are not able to influence the mechanical properties of root canal dentin. This conclusion might be due to the following factors as polymerization that occurred along the sealer-dentin interface in the coronal part of the root is possibly affected by oxygen inhibition; creeping of incompletely polymerized resinous sealers, which results in failure along the sealer-dentin interface; presence of residual monomers in the root canals; and most importantly, the low cohesive, tensile, compressive strengths and modulus of elasticity of the currently available root filling materials when compared with dentin, with the former behaving as elastomers that dissipate instead of transmitting stresses. In addition, the extremely unfavorable cavity geometry (ie, C-factor) of root canals causes gaps along the dentin/sealer interface during polymerization of the methacrylate resin–based sealers.¹⁹,²⁰

It can be concluded that the most recently introduced self-adhesive type bondable root canal sealers are also associated with the additional benefits reduced application steps and overall improvements in their user friendliness. Accordingly, the objectives of this review were to clarify the behavior of these sealers and to identify, if possible, evidence-based support on the merits of their clinical use.²¹

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