Journal of the Formosan Medical Association (2012) 111, 340—346

Available online at www.sciencedirect.com

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ORIGINAL ARTICLE

In vitro evaluation of bond strength and sealing ability of a new low-shrinkage, methacrylate resin-based root canal sealer

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Received 23 May 2011; received in revised form 25 August 2011; accepted 27 August 2011

KEYWORDS
bond strength;
microleakage;
push-out test;
root canal sealer;
sealing ability

Background/Purpose: The aim of this study was to evaluate a new low-shrinkage, methacrylate resin-based root canal sealer (LSRCS) to determine its bond strength in radicular dentin and sealing ability.
Methods: Extracted single-root teeth were randomly divided into three experimental groups ($n = 20$) for obturation with Gutta-percha (GP)/AH Plus, Resilon/Epiphany, or Resilon/LSRCS. One-half of each experimental group was analyzed by the push-out test, using sections perpendicular to the long axis divided into 1 mm serial slices and a universal testing machine to detect the loading force. The other half was analyzed by the dye penetration test using 2% methylene blue solution (pH = 7) and measuring dye leakage under a stereomicroscope.
Results: The push-out test revealed significant differences ($p < 0.05$) in bond strength produced by the three sealers; the GP/AH Plus group showed the highest bond strength, followed by Resilon/LSRCS and Resilon/Epiphany. According to the microleakage data, GP/AH Plus showed the least dye penetration, which was significantly less than Resilon/Epiphany and Resilon/LSRCS. There was no difference in apical leakage between Resilon/Epiphany and Resilon/LSRCS.
Conclusion: The newly developed LSRCS, although not superior to AH Plus in bond strength or sealing ability, possesses monoblock potential and application prospects.

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0929-6646/$ - see front matter
doi:10.1016/j.jfma.2011.08.023

Introduction

Root canal sealer (RCS) is crucial to obtain perfect obturation of the intricate root canal anatomy and to compensate for core materials limited bonding abilities to the radicular dentin. The ideal RCS will completely attach the defective bonds, entomb the remaining bacteria, and achieve a hermetical seal of the root canal system.[1] The indispensible criteria of an ideal RCS include: effective adhesion to both the radicular dentin and the core root canal filling materials, no shrinkage upon setting, biocompatibility, and suitable working time.[2] Methacrylate-based RCS were clinically introduced in the mid-1970s and have since experienced four generations of development, evolving from non-etching to self-etching adhesion potential.[3] Although they have imperfect physiochemical properties and biocompatibility, the resin-based sealers have remained the popular choice for creating an impervious seal, due to their excellent bonding ability. More recently, the dual-curable methacrylate sealer Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA) was developed for use with Resilon core materials (Resilon Research LLC, Madison, CT, USA) to achieve a monoblock structure of a continuous resin bonded to the dentin wall, thereby providing an alternative to the conventional root canal filling system.[4]

After a root canal procedure, normal contraction stress along the interfaces of the radicular dentin seal can decrease the bond strength of the adhesive system. Polymerization shrinkage which occurs during setting, when monomer molecules are converted into a crosslink-network, is one of the most critical factors affecting resistance to contraction stress.[5] Bisphenol-A-diglycidyl dimethacrylate (Bis-GMA) is the most commonly used base monomer in methacrylate RCS. This bulky dimethacrylate monomer (molecular weight = 512) was synthesized by Bowen in 1965, and features relatively low polymerization shrinkage, rapid hardening, and low volatility[6]; however, the methacrylate sealer is subject to microleakage, which has been implicated in eventual clinical failure. To reduce the microleakage, several Bis-GMA analogues and substitutes have been developed which produce less shrinkage in the setting phase. For example, Khatri et al synthesized urethane derivatives of Bis-GMA which exhibited lower viscosity and higher hydrophobicity than Bis-GMA.[7] Ge et al later developed another low shrinkage methacrylate monomer by adding bulky substituent groups, to facilitate improved double bond conversion and decreased polymerization shrinkage.[8] Thus, it was demonstrated that increasing the molecular weight of the monomer represented an effective strategy to decrease polymerization shrinkage.

In more recent efforts to further diminish the polymerization shrinkage, He et al synthesized a novel, low-shrinkage and high molecular weight (574) dimethacrylate monomer 4′4-AMBHMB.[9,10] A system using 4′4-AMBHMB mixed with the dental resin monomer triethylene glycol dimethacrylate (TEGDMA) produced less polymerization shrinkage, and featured decreased solubility and water sorption as compared to the Bis-GMA/TEGDMA commonly used in resin-based RCS. In our most recent work, the 4′4-AMBHMB/TEGDMA (50:50 optimum proportion) was used to create a new low-shrinkage, methacrylate resin-based RCS (LSRCS). The composition of LSRCS also included the monomers (N,N-dimethylamino)ethyl-methacrylate (DMAEMA) and camphorquinone (CQ), at optimum proportion of 2:4, and the fillers hydroxyapatite (HA), barium sulfate ($BaSO4$) and zinc oxide (ZnO), with optimum proportion of 9:3:2. The LSRCS displayed good physicochemical properties and biocompatibility.[9–11] Therefore, we extended our study to evaluate the interfacial bond strength and apical sealing ability of this newly synthesized resin-based sealer, and perform comparative analysis between LSRCS and the commercial RCSs AH Plus and Epiphany.

Materials and methods

Selection of teeth

For this study, intact, caries-free human maxillary incisors with single-straight roots, which had been extracted for periodontal reasons, were selected. Informed consent for the use of the biosample in scientific research was obtained in conjunction with study approval by the Ethics Committee of Guanghua School of Stomatology, Sun-yat Sen University. Teeth were carefully examined for open apices, cracks, or resorptive defects, which led to sample exclusion. The included samples ($n = 75$) were stored in 0.9% sodium chloride containing 0.02% sodium azide at 4 °C until use. All the roots were radiographed to confirm root canal patency and single. Crowns were sectioned perpendicularly to the long axis at the cemento-enamel junction using a water-cooled fissure bur to make the length proximal to 14 mm.

Instrumentation and obturation of root canal

The root canals were accessed by using a size 15 K-file until visualized at the apical foramen. The working length of each root was established by subtracting 1 mm from the foramen. The canal spaces were mechanically shaped by using rotary ProTaper nickel-titanium files (250 rpm; Dentsply Maillefer, Tulsa, Oklahoma, USA), following the manufacturer's instructions and using a crown-down technique. The preparation of the apical third was completed by use of a ProTaper file F3. All canals were irrigated with 10 mL of 5.25% sodium hypochlorite (NaClO), followed by a wash with 10 mL of 17% ethylenediaminetetraacetic acid (EDTA). Finally, the root canals were flushed with 10 mL of distilled water to remove any residual EDTA or NaClO, and blot-dried with sterile paper points.

The 75 root samples were randomly divided into three experimental groups ($n = 20$; for obturation with Gutta-percha (GP)/AH Plus, Resilon/Epiphany, or Resilon/LSRCS) and three control groups ($n = 5$). Each experimental group was subdivided into two groups ($n = 10$; for push-out or dye penetration test). All the roots were filled using the lateral condensation technique. Group 1 roots were filled with AH Plus and 0.04 taper GP points. Group 2 roots were painted with self-etching primer for 30 seconds using microbrushes and paper points to remove the excess primer; then, Epiphany was applied to the canal, followed by 0.04 taper Resilon points. Group 3 roots were filled as in group 2, but