THEMATIC ISSUE – MATERIALS

Dental Repair Material: A Resin-Modified Glass-Ionomer Bioactive Ionic Resin-Based Composite
Dental Repair Material: A Resin-Modified Glass-Ionomer Bioactive Ionic Resin-Based Composite

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Abstract: This report documents treatment and repair of three carious teeth that were restored with a new dental repair material that features the characteristics of both resin-modified glass-ionomer restorative cement (RMGI) and resin-based composite (RBC). The restorative products presented are reported by the manufacturer to be the first bioactive dental materials with an ionic resin matrix, a shock-absorbing resin component, and bioactive fillers that mimic the physical and chemical properties of natural teeth. The restorative material and base/liner, which feature three hardening mechanisms, could prove to be a notable advancement in the adhesive dentistry restorative materials continuum.

While it may seem puzzling to designate a dental restorative material as a “resin-modified glass-ionomer bioactive ionic resin-based composite,” there is reason to believe that this is scientifically accurate. The three carious teeth that were treated and documented in this report were restored with a novel dental repair material that features characteristics of both resin-modified glass-ionomer restorative cements (RMGIs) and resin-based composites (RBCs).

In 2013, Pulpdent® Corporation acquired premarket approval from the US Food and Drug Administration (510(k) approval) for two materials that were to become ACTIVA™ BioACTIVE-RESTORATIVE™ and ACTIVA™ BioACTIVE-BASE LINER™. (This report will refer to these materials as “ACTIVA-RESTORATIVE” and “ACTIVA-B/L.”) The 510(k) determination
was based on the fact that the new products were considered equivalent to resin-modified glass-ionomers already marketed in dentistry. However, even though the new materials contain the glass particles and polyacid components of RMGIs, which undergo the acid/base neutralization hardening reaction of all glass-ionomer systems, they are also formulated with a “bioactive ionic resin matrix,” having both a light-polymerization ability and a chemical cure. Thus, there are three hardening mechanisms involved with the ACTIVA products.

Restorative Material “Continuum”
Burgess et al.1 and Berg2 described an adhesive dental restorative material “continuum.” Based on chemical make-up, physical properties, advantages, and disadvantages, one is able to classify such materials and judge what would be the best use for any one product. The most desirable product would be one that possesses all the advantages of glass-ionomer systems (ie, fluoride release and “recharging,” chemical bonding to tooth structure, coefficient of thermal expansion similar to that of tooth structure, biocompatibility, proven history) combined with those of resin-based composites (ie, high fracture strengths, excellent wear and erosion resistance, excellent adhesion using the acid-etch technique, high polishability). In addition, such a product would eliminate the drawbacks of the glass-ionomer systems (ie, lower fracture resistance and wear/erosion resistance than RBCs) and the resin-based composites (ie, eventual hydrolysis of the resin/dentin bond, post-treatment tooth sensitivity, polymerization shrinkage).

Characteristics of an ideal adhesive dental repair material have been succinctly outlined.3 The material should chemically bond to enamel and dentin. It should also be therapeutic by releasing fluoride ions that are incorporated into adjacent dentin and enamel, rendering that tooth structure less soluble to acid challenge. It should also have an antimicrobial effect by virtue of its fluoride content and have equivalent coefficient of thermal expansion to that of tooth structure so that the mass of material has sufficient dimensional stability, thereby minimizing marginal breakdown. Additionally, the material should not shrink or expand during the hardening reaction. It should be insoluble in oral fluids and foodstuffs (ie, erosion resistance). An ideal adhesive dental repair material should also have high resistance to wear from impact forces and stresses from occlusion and mastication, along with wear-and-tear resistance from toothbrushing. High cohesive strength is another characteristic, as is resistance to both initial fracturing and propagation of fractures. Finally, it should be tooth-colored, highly polishable, and have easy handling characteristics, including “on command” hardening (such as photopolymerization).

According to the manufacturer, ACTIVA-RESTORATIVE and ACTIVA-B/L are the first bioactive dental materials with an ionic resin matrix, a shock-absorbing resin component, and bioactive fillers that mimic the physical and chemical properties of natural teeth. They are durable and wear- and fracture-resistant, and they chemically bond to teeth, seal against bacterial microleakage, and release and recharge with calcium, phosphate, and more fluoride ions than glass ionomers. In addition, ACTIVA contains no bisphenol A (BPA), bisphenol A glycidyl methacrylate (bis-GMA), or BPA derivatives.4 The manufacturer has been involved in considerable in-house and university-based testing of these products over the past several years, the results of which are either in press in dentistry journals or have already been published.5 6 The company’s website features

**TABLE 1**

<table>
<thead>
<tr>
<th>Physical Properties of the Two ACTIVA Materials</th>
<th>RESTORATIVE</th>
<th>BASE/LINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-cure setting time</td>
<td>20 sec</td>
<td>20 sec</td>
</tr>
<tr>
<td>Depth of light-cure</td>
<td>4 mm</td>
<td>4 mm</td>
</tr>
<tr>
<td>Self-cure setting time at 37°C</td>
<td>2 min</td>
<td>2 min</td>
</tr>
<tr>
<td>% filler by weight</td>
<td>56%</td>
<td>45%</td>
</tr>
<tr>
<td>% reactive glass by weight</td>
<td>21.8%</td>
<td>19.3%</td>
</tr>
<tr>
<td>Fluoride release, 1 day</td>
<td>230 ppm</td>
<td>360 ppm</td>
</tr>
<tr>
<td>Fluoride release, 28 days (cumulative)</td>
<td>940 ppm</td>
<td>1,300 ppm</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>102 MPA/14,790 psi</td>
<td>86 MPA/12,470 psi</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>4.3 GPa</td>
<td>3.7 GPa</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>280 MPA/40,600 psi</td>
<td>226 MPA/32,770 psi</td>
</tr>
<tr>
<td>Diametral tensile strength</td>
<td>42 MPA/6,090 psi</td>
<td>37 MPA/5,365 psi</td>
</tr>
<tr>
<td>Water sorption, 1 week</td>
<td>1.65%</td>
<td>2.30%</td>
</tr>
<tr>
<td>Polymerization shrinkage</td>
<td>1.7%</td>
<td>n/a</td>
</tr>
</tbody>
</table>
results of studies comparing the ACTIVA products with RBCs and RMGIs\textsuperscript{7}; the properties evaluated include compressive strength, diametral tensile strength, flexural strength (base/liners), compressive strength (base/liners), wear of ACTIVA-RESTORATIVE versus glass-ionomers, RMGIs, and “flowable composites,” volume

wear of ACTIVA and three other materials, deflection at break (a test of toughness/ flexibility to absorb stress and resist fracture), comparative water absorption, water solubility, and radiopacity (equivalent to 1.5 mm of aluminum). In summary, those test results show that the two materials have physical characteristics closely resembling the strengths and wear resistance of RBCs. Physical properties for the two ACTIVA materials listed by the manufacturer\textsuperscript{8} are shown in Table 1.

Because the physical properties of ACTIVA products rival those of the resin-based composites tested, combined with having bioactivity capabilities consistent with glass-ionomer systems, these new products are seemingly unique and unprecedented in the dental restorative materials continuum.\textsuperscript{1,2}

The two materials (ACTIVA-RESTORATIVE and ACTIVA-B/L) can be mixed and applied with Pulpdent’s gun-type dispensing unit (Figure 1). The tip blends the two pastes ideally as they are expressed through the mixing/delivery tube. Another method of delivery is to express the two pastes onto a mixing pad, blend them with a spatula, and load the paste into an AccuDose\textsuperscript{8} Low Viscosity tip (Centrix, www.centrixdental.com) for syringe injection. Care must be taken during hand-spatulation to avoid incorporating air bubbles into the mixture.

**Case 1**

A 10-year-old boy had a mesio-occlusal caries lesion of the maxillary right primary second molar (Figure 2). Using standard local infiltration anesthesia and “slit dam” rubber dam isolation,\textsuperscript{9} the tooth was restored as follows:

After a wooden wedge was inserted to protect the papilla and eliminate proximal bleeding, the mesio-occlusal outline form was prepared using a cylindrical diamond bur (Figure 3). Caries debridement followed, using a slow-speed round bur. After completion of the preparation, a contoured matrix strip was placed and stabilized with firm insertion of the wedge, which caused slight separation of the teeth, assuring tooth contact after treatment (Figure 4).

ACTIVA-RESTORATIVE was injected slowly, from the bottom of the preparation to the top, taking great care to cover every surface with the cement while avoiding air incorporation (Figure 5). Only one portion was used. After a delay of 20 seconds to allow for the acid component to react with the tooth surface, the visible light beam (1,200 mW cm\textsuperscript{2}) was applied for 20 seconds.

The filling material was injected to excess, overlapping all cavo-surface margins (Figure 6), and then a large round diamond bur was used at slow speed to sculpt the occlusal surface (Figure 7). This was followed by the use of a carbide bur (Fissurotomy\textsuperscript{®} Bur, SS White, www.sswhitedental.com) to shape the marginal ridge and trim axial “flash” (Figure 8). A self-etching resin bonding agent (Adper™ Prompt™ L-Pop™ Self-Etch Adhesive, 3M ESPE, www.3MESPE.com) was applied to the tooth surface, bonding the restoration to the tooth.

**Fig 2.** Case 1: Mesio-occlusal caries of primary second molar in 10-year-old patient. **Fig 3.** Outline form cut with cylindrical diamond bur. Wooden wedge in place during tooth preparation. **Fig 4.** Preparation completed, matrix strip placed, and wedge firmly inserted. **Fig 5.** ACTIVA-Restorative injected in one portion, to overfill.
was painted over the surface and light-cured after a 20-second delay. Figure 16 shows the tooth immediately after treatment, before occlusal evaluation (Figure 17).

Figure 17 also reveals a caries lesion on the mesial surface of the maxillary first molar. The tooth was anesthetized and retraction cord placed. Carious substance was debrided with a slow-speed round bur (Figure 18), and the cavity preparation was filled with one portion of ACTIVA-RESTORATIVE. The restoration was finished and polished with aluminum-oxide disks. Four months after treatment, the tooth was photographed (Figure 19), showing ideal restoration of the mesial surface to original form and surface luster.

The restored mandibular molar is also shown again 4 months after treatment in Figure 20.

Discussion
The authors have used the ACTIVA products for less than a year, and are therefore unable to predict long-term durability and longevity of these restorations in children and adolescents. However, the senior author (TPC) has placed more than 210 primary tooth restorations and more than 180 permanent tooth restorations using ACTIVA-RESTORATIVE from March 2014 through November 2014 (as of press time) and has observed the following:

- The material handles like most injectable resin-based composites.
- No bonding agent is needed when repairing primary teeth.
material is left alone for about 20 seconds after injection to allow the polyacid component to etch the tooth structure. As in most cavity preparations, mechanical undercutting augments retention achieved with adhesive bonding.

- “White line” margins, typical of freshly finished bonded RBC restorations, are conspicuously absent, which is probably attributable to low polymerization shrinkage.
- Standard phosphoric acid-etching protocol or use of a self-etching bonding agent has been used for permanent tooth repair. The authors believe this gives more assurance of complete etching and minimizes marginal leakage. Research is needed to reveal if phosphoric acid-etching or a self-etching bonding agent significantly improves ACTIVA-RESTORATIVE and ACTIVA-B/L bonding to dentin and enamel in permanent teeth.
- The chemical cure of the ACTIVA products is reassuring to the dentist. If the light-beam penetration is not ideal, material hardening is completed by the chemical curing reaction and the acid/base neutralization hardening reaction of the glass-ionomer components.
- The authors have received no complaints of postoperative tooth sensitivity with or without placement of a standard RMGI base/liner or an ACTIVA-Base/Liner.
- The results seen in this report, albeit short-term, are typical of all other ACTIVA restorations the authors have completed and subsequently observed.

The authors consider that ACTIVA-RESTORATIVE and ACTIVA-B/L could prove to be major advancements in the adhesive dentistry restorative materials continuum. Independent, continuing in-vitro and in-vivo studies to verify or refute the authors’ first half-year clinical observations need to be pursued, to offer further insight into these intriguing products.

**DISCLOSURE**

The authors have no affiliations with the product manufacturers mentioned in this article.

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**REFERENCES**

1. Burgess JO, Norling BK, Rawls HR, Ong JL. Directly placed esthetic


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**Fig 15.** Light-beam exposure for 20 seconds. **Fig 16.** Following occlusal surface sculpting and self-etch adhesive application, completed occlusal repair is shown. **Fig 17.** Occlusal contacts evaluated with articulating paper. Note mesial surface caries lesion of maxillary molar. **Fig 18.** Retraction cord in place, tooth preparation completed. **Fig 19.** Mesial restoration, 4 months after treatment. **Fig 20.** Mandibular molar photographed 4 months after treatment.