

Overview and recent advances in composite resin: A review

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Abstract

Composite dental restorations represent a unique class of biomaterials with severe restrictions on biocompatibility, curing behavior, esthetics, and ultimate material properties. These materials are presently limited by shrinkage and polymerization induced shrinkage stress, limited toughness, the presence of unreacted monomer that remains following the polymerization, and several other factors. Fortunately, these materials have been the focus of a great deal of research in recent years with the goal of improving restoration performance by changing the initiation system, monomers, and fillers and their coupling agents, and by developing novel polymerization strategies. This article discusses the advances in resin restorative materials.

Key words: Antimicrobial, Condensable, Indirect composite, Nano-composite, Self-healing

INTRODUCTION

Composite resins have been introduced into the field of conservative dentistry to minimize the drawbacks of the acrylic resins that replaced silicate cement in the 1940s. In 1962, Bowen developed the bisphenol A glycidyl methacrylate (BISGMA) monomer in an attempt to improve the physical properties of acrylic resins, as their monomers were only allowed linear chain polymers to be formed. Although Bowen's formulation has been available for more than 30 years, the chemistry has remained relatively unchanged. As a result, the mechanical properties also have not improved substantially. The purpose of this article is to discuss new resin systems exhibiting substantial improvements in wear resistance and clinical performance.¹

Direct Composite Resin

Condensable/packable or polymeric rigid inorganic matrix material

This new concept was developed by Dr. Lars Ehrnford of Sweden in 1995. This system is composed of a resin matrix and an inorganic ceramic component. Rather than incorporating the filler particles into the composite resin matrix, devised a unique system by which the resin is incorporated into the fibrous ceramic filler network. This mainly consists of aluminum oxide and silicon dioxide glass particles or barium aluminum silicate or strontium glasses. The glass particles are liquefied to form a molten glass which is forced through a die to form thin strands of glass fibers.

The diameter of these fibers was approximately 2-3 μm . These glass fibers were crushed into small fragments and then reheated to a sufficient temperature to cause superficial fusion of glass fibers at selected sites (silanization), this forms the continuous network of small chambers or cavities (dimensional interfacial chambers = 2 μm). The manufacturers then infiltrate these spaces within the fibrous network with an optimized resin depending on the final application use of the restorative material (BISGMA/urethane dimethacrylate resin). This concept provides a basis for fabricating packable or condensable

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posterior composite resin. Traditional light-cured hybrid resin composites cannot be bulk placed because of excessive polymerization shrinkage and the inability to adequately light-polymerize the resin beyond a 2 mm depth. Manufacturers prescribe bulk placement of packable composites was claiming decreased polymerization shrinkage due to increased filler loading and a reported depth of cure reaching 5 mm. However, certain packable resin composites demonstrated polymerization contraction similar to or higher than conventional hybrid composites. The completeness of polymerization of some packable resin composites was significantly less with bulk cure in comparison to standard incremental polymerization.¹

Packable resin composites were developed to restore surfaces that previous resin composites could not. However, certain principles still hold true. The faciolingual width of the cavity preparation should be no larger than one-third the intercuspal distance and replacement of cusps with packable resin composite are contraindicated. A Class II restoration should ideally end on sound enamel. If this is not present at the cervical margin other procedures such as an “open sandwich technique” should be used. In this glass ionomer is placed as the initial increment filling the first couple of millimeters of the box. Glass ionomers predictable bond to dentin reduces microleakage compared to a resin-dentin margin. Centric stops should be on tooth structure. Clinical signs of excessive wear of bruxing and grinding should be absent. One of the most critical factors for long-term success is the ability to isolate with a rubber dam. Avoiding saliva and blood contamination of the prepared enamel and dentin surfaces is vital to achieve a proper bond. Packable resin composite should not be viewed as a time saver as bulk placement of packable resin composite is not recommended and may compromise the long-term success of the restoration.²

Flowable Composite

A newer type of composite was released in 1996 that has been termed a “flowable composite” because of its low viscosity and ability to be syringed into a cavity preparation with a needle tip. While the heavy-bodied consistency of traditional packable composites is very desirable in gaining the control to shape aesthetic and functional restorations, clinicians have found that a material that can flow into cavity preparations has an important role, especially where the deposition of material into a tight space is required.

Most of the flowable composites presently available are not filled, generally containing from 56% to 70% filler by weight. Accordingly, they have reduced mechanical properties such as a higher susceptibility to wear, a higher polymerization shrinkage, and lower flexural strength. Flowable composite resin materials can be useful not only

as a liner but to build up cavity preps, to block out small undercuts and to use as an indirect or direct pulp cap.³ Low-modulus flowable resin composites have been described as potentially radiopaque “filled adhesives” with implications for improved clinical dentin bonding. In contrast, restorative composites have a relatively high modulus of elasticity, and it has been suggested that this high stiffness contributes to their inability to compensate for contraction stress during polymerization. This can lead to either bond failure or fracture of the tooth structure, resulting in microleakage and post-operative sensitivity. Employing an intermediate layer of low-modulus composites can relieve some of the contraction stress during polymerization. Application of increased thickness of low stiffness adhesive has a similar effect. Use of flowable composites in conjunction with the very high viscosity, high-modulus packable composites is a common clinical technique. However, the effects of the higher-than expected polymerization shrinkage of the flowable material (because of lower filler loading) and the effects of possible flexure of the restoration when it is supported by the lower modulus flowable “liner” are unknown.⁴

Indirect Composite Resin

Because of the major clinical problems clinicians have experienced with direct posterior composite resins, the indirect inlay or onlay systems were introduced. Since the restoration is made on a die rather than directly on the tooth, the restoration has superior adaptation, contour and proximal contact. On the whole, there is a dramatic improvement in the general clinical performance. A number of highly improved indirect resin restorative systems have been introduced with unusually good properties like wear resistance, esthetics, marginal adaptation, control over polymerization shrinkage.

Touati and Mörmann introduced the first generation of indirect resin composites (IRCs) for posterior inlays and onlays in the 1980s. Direct resin composites were composed mostly of the organic resin matrix, inorganic filler, and a coupling agent. The first generation IRCs had a composition identical to that of the direct resin composite marketed by the same manufacturer and the materials also bore names similar to that of the direct materials. For inlay composites, an additional or secondary cure is given extraoral, which improves the degree of conversion and also reduces the side effects of polymerization shrinkage. The only shrinkage that is unavoidable is that of the luting cement. It was observed that the first generation IRCs showed improved properties only in lab studies but had failures in clinical studies. The clinical failures endured with the first generation composites and the limitations faced with ceramic restorations led to the development of improved second generation composites.

The second generation composites have a “microhybrid” filler with a diameter of 0.04-1 μ , which is in contrast to that of the first generation composites that were microfilled. The filler content was also twice that of the organic matrix in the latter composites. By increasing the filler load, the mechanical properties and wear resistance is improved, and by reducing the organic resin matrix, the polymerization shrinkage is reduced. The new composite resins like Artglass and Belle Glass HP contain high amounts of filler content, which make them adequate for restoring posterior teeth.⁵

Nanocomposites

Nanotechnology may provide composite resins with a dramatically smaller filler particle size that can be dissolved in higher concentrations and polymerized into the resin system. The molecules in these materials can be designed to be compatible when coupled with a polymer and provide unique characteristics (i.e., physical, mechanical, optical). Currently, the particle sizes of conventional composites are so different from the structural sizes of hydroxyapatite crystals, dental tubules, and enamel rods, compromises in adhesion between the macroscopic (40-0.7 nm) restorative material and the nanoscopic (1-10 nm in size) tooth structure are potential. Nanotechnology can, however, improve this continuity between the tooth structure and the nanosized filler particle and provide a more stable and natural interface between the mineralized hard tissues of the tooth and these advanced restorative biomaterials.⁶ Studies have shown that nanocomposites show greater fracture toughness and adhesion to tooth structure.⁷

Antimicrobial Composite

Antimicrobial properties of composites may be accomplished by introducing agents such as silver or one or more antibiotics into the material. Microbes are subsequently killed on contact with the materials or through leaching of the antimicrobial agents into the body environment.²

Silver and titanium particles were introduced into dental composites, respectively, to introduce antimicrobial properties and enhance the biocompatibility of the composites.¹ Several reports have described the incorporation of a methacryloyloxydodecyl pyridinium bromide monomer in composite resins that showed no release of the incorporated monomer but still exhibited antibacterial properties.⁸ Alkylated ammonium chloride derivatives and chlorhexidine diacetate have also been introduced as an antimicrobial agent into dental composites.

Stimuli Responsive Composite

Stimuli-responsive materials possess properties that may be considerably changed in a controlled fashion by external

stimuli. Such stimuli may be for example changes of temperature, mechanical stress, pH, moisture, or electric or magnetic fields. Stimuli-responsive dental composites may be quite useful for example for “release-on-command” of antimicrobial compounds or fluoride to fight microbes or secondary caries, respectively.⁸

Fiber Reinforced Composite

Fiber-reinforced composites have numerous industrial and aerospace applications because they are light, strong and non-flammable. However, with respect to clinical dentistry, they are relative newcomers into the spectrum of prosthodontic treatment options.⁹ Over the years, these materials have evolved to the extent that they can be used for both direct and indirect restorations.¹⁰

Self-healing Composite

Materials usually have a limited lifetime and degrade due to different physical, chemical, and biological stimuli. These may include external static (creep) or dynamic (fatigue) forces, internal stress states, corrosion, dissolution, erosion, or biodegradation. This gradually leads to a deterioration of the material structure and finally failure of the material.

One of the first self-repairing or self-healing synthetic materials reported interestingly shows some similarities to resin-based dental materials, since it is resin-based. This was an epoxy system which contained resin filled microcapsules. If a crack occurs in the epoxy composite material, that microcapsules are destroyed near the crack and release the resin. The resin subsequently fills the crack and reacts with a Grubbs catalyst dispersed in the epoxy composite, resulting in a polymerization of the resin and a repair of the crack. Similar systems were demonstrated to have a significantly longer duty cycle under mechanical stress *in situ* compared to similar systems with the self-repair.¹¹

CONCLUSION

There is much room for the improvement and further development of resin-based dental materials, such as composites. A new quality of dental composites may, however, be created if nanotechnology is used and other new developments in material science and biomaterials are considered in composites in the future.

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