RECENT ADVANCES IN COMPOSITE RESINS- A REVIEW

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ABSTRACT

The introduction of resin-based dental materials around the mid of the last century was a revolution in restorative dentistry. The early formulations were characterised by numerous problems like improper handling characteristics, polymerization shrinkage, improper marginal adaptation, inappropriate proximal contact and most importantly secondary caries and inadequate wear resistance. The need to improve shrinkage properties and wear resistance is obvious for dental composites and a vast number of attempts have been made to accomplish these aims. Based on recent clinical information, it appears that major successes have been achieved in reaching the goal. This article discusses the advances in resin restorative materials.

KEYWORDS: ***Condensable composite, Flowable composite, Artglass, Belle glass HP, nanocomposites, Antimicrobial, Smart material, Self repair.***

INTRODUCTION

Acrylic resin was introduced to the dental profession in the mid 1950s. Since their introduction, acrylic based materials have continued to play a major role in restorative and prosthetic dentistry. The potential for greater application of resins came about with the introduction of the bisphenol A glycidyl methacrylate, or BIS-GMA, by Bowen in the early 1960s. This formulation possessed a higher molecular weight and therefore better mechanical properties and reduced polymerization shrinkage, the newer polymer offered potential for much greater applications that included anterior and posterior composite resin restorations, indirect inlays/onlays, pit and fissure sealants and more wear resistant denture teeth.

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.

Direct composite resin

Condensable/Packable or Polymeric rigid inorganic matrix material (PRIMM)

This new concept was developed by Dr. Lars Ehrnford of Sweden[1] 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, he devised a unique system by which the resin is incorporated into the fibrous ceramic filler network. The filler mainly consists of aluminium oxide and silicone dioxide glass particles or barium aluminium silicate or strontium glasses. The glass particles are liquefied to form molten glass which is forced through a die to form thin strands of glass fibers. The diameter of these fibers being approximately 2-3 µm. These glass fibers are crushed into small fragments and then reheated to a sufficient temperature to cause superficial fusion of glass fibers at selected sites (silanation). This forms a 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 upon the final application use of the restorative material (BISGMA/UDMA resin).This concept provides a basis for fabricating packable or condensable posterior composite resin.

Colloidal silica ultrafine particles are also incorporated to control the handling characteristics such as viscosity, resistance to flow, condensability and reduced stickiness. Greater the condensation pressure used, greater is the expression of residual resin, and greater is the density of the inorganic phase. Hence this new concept resulted in advantages like better marginal adaptation, lower potential for incorporation of microscopic porosities, lesser polymerization shrinkage (as any polymerization shrinkage that takes place will be localized within the small ceramic chambers/spaces), optimal mechanical characteristics like flexural strength, modulus of elasticity and coefficient of thermal expansion and greater wear resistance.

Flowable composites

Flowable composites were developed mainly in response to requests for special handling properties for composite resins rather than any clinical performance criteria. Hence their physical properties had limitations.

They were created by reducing the filler content of traditional hybrid composites and retaining the same filler size and adding increased resin to reduce viscosity of the mixture. Since the filler content was reduced in these composites they lack sufficient strength to withstand high stresses and because of the increased resin content these composites show more polymerization shrinkage and have lower elastic moduli and high fracture toughness. They cannot be used in high stress bearing areas and also difficult to manipulate because of stickyness.

Indirect composite resins[1]

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.

Artglass[1]

Artglass is a non conventional dental polymer marketed since 1995. It is most commonly used in inlays, onlays and crowns. The resin matrix is composed of BISGMA/UDMA. This configuration provides a higher level of cross linking and better control over the positions along the carbon chain where cross linking occurs. This aids in improving the wear resistance and other physical and mechanical properties of the resin matrix. Filler is radiopaque barium glass (mean particle size 0.7 µm). A moderate amount of colloidal silica is also incorporated for the purpose of enhancing certain handling characteristics.

Artglass is photocured using a special xenon stroboscopic light. The emission ranges from 320 – 500nm. This range is significant because excitation of the initiator, camphoroquinone, is optimized at about 470 nm.

Artglass has the advantages of having considerably more wear resistant than conventional light cured composites, good marginal adaptation, esthetics and superior proximal contact.

Belleglass HP[1]

Belleglass HP was introduced by Belle de St. Claire in 1996 as an indirect restorative material. Resin matrix contains BISGMA and fillers. The Belleglass is polymerized under pressure of 29 psi at elevated temperature of 138^{0}C and in the presence of nitrogen, an inert gas. The elevated temperature increases the polymerization rate. The increased atmospheric pressure reduces the vaporization potential of the monomers at elevated temperatures. Use of nitrogen gas during polymerization process relates to an increase in the wear resistance i.e. nitrogen provides an oxygen free environment, which in turn results in higher levels of polymerization; more translucency of cured mass. Oxygen if gets entrapped in the composite, it interferes with polymerization and reduces translucency. It is esthetically appealing and highly wear resistant.

Nanocomposites[2]

The use of nanoparticles in dental composites is not new. Colloidal silica particles of a diameter of approximately 40 nm have been in use in dental microfilled and hybrid composites for more than 10 years. Nanoparticle filled composites exhibit outstanding esthetics, are easy to polish and posses an enhanced wear resistance. Nanoparticle fillers may include colloidal silica or Ormocers, such as in Ceram X from Dentsply. Similar particles may be used in resin-based bonding systems. Nanoparticle particle filled dental composites may show an enhanced fracture toughness and adhesion to tooth tissue.

Antimicrobial materials

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 biocompatibility of the composites.[3] Dental composites containing 1% (w/w) quaternary ammonium polyethylenimine(PEI) nanoparticles were tested for their antimicrobial activity. The antibacterial properties of these composites were based on contact mechanism rather than on leaching. The mechanical properties were not significantly affected by introducing the PEI nanoparticles. The antimicrobial effect lasted for at least 1 month.[4] Alkylated ammonium chloride derivatives[5] and chlorhexidine diacetate[6] have also been introduced as antimicrobial agent into dental composites.

Stimuli response materials / Smart materials[2]

Stimuli response 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.

Self-repairing materials[2]

One of the first self-repairing 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, some of the 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 repair of the crack.

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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