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REVOLUTIONARY EXCELLENCE OF 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 characterized 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: Esthetic Dentistry, Composite Resins, Different variants in Composite resins.

INTRODUCTION

The basic and primary goal of Restorative Dentistry is to re-establish the function and esthetics of the tooth. In the evolution of restorative materials there were succession between various cements, as the principle material of choice in 19th century was amalgam, because functional restoration was the need for the hour. However esthetic concern gave the inevitable pavement for tooth colored restorative material and adhesive Dentistry without compromising their function. Composite resins claimed the throne with the alliance of minimal invasive dentistry and stands as a critical candidate in the clinical implication for various dental procedures. Considering the preservation of vital tooth structures the concept of restorative dentistry, "extension for prevention" was over ruled by "restriction with conviction". Many short comings of composite resin were improved with the newer and modified chemical compositions and addition of adjuvant cements.

Compositional integration of composite resin

According to Lutz et al,[1] filled restorative resins consist of three-dimensional combinations of a minimum of two chemically different materials with a surface interfacial phase. The 3 phases are: the matrix phase, the surface interfacial phase, and the dispersed phase. Each resin also included an accelerator-initiator system to begin and complete polymerization. The chemically cured composites generally use an amine-peroxide system, whereas the light-cured resins use a di-ketone amine system which is activated by the intense blue light. In addition, pigments and opaquers are added to control transluency and shade.

The resin matrix is a dimethacrylate oligomer such Bis-GMA or urethane-diacrylate. The surface interfacial phase consists of either a bipolar coupling agent to bind the organic resin matrix to the inorganic fillers, or a copolymeric of homopolymeric bond between the organic matrix and partial organic filler. The degree of interfacial adhesion and chemical stability is critical for successful clinical use of any composite resin.[2]

Lutz et al[1] classified the dispersed phase based on the three major classes of filler particles used. Traditional macrofillers consist of quartz, glass, borosilicate, and ground or crushed ceramic. The diameter of macrofillers particles range from 0.1 to 100A.055micro meter in size. Microfillers are usually pyrogenic silica which are amorphous, completely dispersed particles of about 0.04A.05.5 micro meter in size. The microfiller-based complexes are usually one of three types: a). splintered pre-polymerized particles of 1 to 200A.055 micro meter in size[3] b). spherical pripolymerized particles of 20 to 30A.055 micro meter in diameter[4] c). agglomerated microfiller complexes of 1 to 25A.055 micro meter in diameter.

Self-cured resins are advantageous where composite resins need to be placed in areas of the mouth where light cannot reach adequatly.[3] However, the visible light-

cured resins have many advantages, including: control over the working time, immediate finishing of a restoration and control over the depth of cure. Since no mixing is required, it means easier handling and minimal porosity, The major benefit is that the restoration will be much more colour stable compared to self cured resins.Therefore, the majority of the composite resins now available are light-cured resins.[4,5]

Polymerisation importance of composite resins
Full polymerisation of the material is determined by the degree of conversion of monomers into polymers, indicating the number of methacrylate groups that have reacted with each other during the conversion process. The factors that influence the degree of conversion of the composite are shown in table below.[6,7]

Table I: Degree of conversion of composite.

Factor	Clinical repercussions
Curing time	It depends on: resin shade, light intensity, box deep, resin thickness, curing through tooth structure, composite filling.
Shade of resin	Darker composite shades cure more slowly and less deeply than lighter shades (60 seconds at a maximum depth of 0.5 mm).
Temperature	Composite at room temperature cure more completely and rapidly.
Thickness of resin	Optimum thickness is 1-2 mm
Type of filler	Microfine composites are more difficult to cure than heavily loaded composites.
Distance between light and resin	Optimum distance < 1 mm, with the light positioned 90 degrees from the composite surface.
Light source quality	Wavelength between 400 to 500 nm. A power density about 600 mW/cm^2 is required to ensure that 400 mW/cm^2 reaches the first increment of composite in a posterior box.
Polymerisation shrinkage	Depends on the amount of organic phase.

Direct Composite Resin
Condensable/Packable or Polymeric rigid inorganic matrix material (PRIMM) This new concept was developed by Dr. Lars Ehrnford of Sweden1 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).[8,9]

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 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.[10]

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.[11,12]

Indirect Composite Resins
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.[13,14]

Artglass

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.[13,14]

Belleglass HP

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 1380C 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.[13,14]

Nanocomposites

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.[15,16]

Antimicrobial Materials Incorporated

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.

Silver and titanium particles were introduced into dental composites, respectively, to introduce antimicrobial properties and enhance biocompatibility of the composites. 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. Alkylated ammonium chloride derivatives and chlorhexidine diacetate have also been introduced as antimicrobial agent into dental composites.[17]

Fiber-Reinforced Composite Resin

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. Over the years, these materials have evolved to the extent that they can be used for both direct and indirect restorations.[18]

Stimuli Response Materials / Smart Materials

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.[19]

Self-Repairing Materials

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.[20]

CONCLUSION

As a restorative material the function ability and esthetic reliability of a composite resin to be used in Dentistry is always a critical determinant. 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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