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Review Article

Recent Advances in Composites: A Literature Review

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Abstract

Although composites form the base of restorative dentistry but these materials are associated with various shortcomings like polymerization shrinkage stress, biocompatibility issues and material properties like limited toughness and 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 review article explains the basics of composites and recent advancements done in these materials to improve their properties.

Keywords: Composites, Methacrylate, Monomers, Photopolymerization, Shrinkage stress

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INTRODUCTION

Enamel and dentin are natural composites.[1] Enamel contains 95wt% inorganic structure out of which 90% - 92% is hydroxyapatite while dentin contains 75wt% inorganic structure. The difference in properties in these two is associated with difference in matrix to filler ratio. This is analogous to synthetic composite.[2] Of all the innovative esthetic materials available today composite restorative materials have assumed a thrust in restorative dentistry. Properly placed composite restorations provide an excellent alternative to traditional metallic posterior restorations.[3,4]

DISCUSSION

Composite restorative material contains number of components in addition to filler and matrix. Early composites based on polymethylmethacrylate were not successful. Major advancement was made by Dr. Ray L Bowen, developed Bis-GMA and organic silane coupling agent.[5,6]

Skinner defined composite as "a compound of two or more distinctly different materials with properties that are superior to or intermediate to those of individual constituents".[4]

According to Philips and Lutz: They defined composite as "3-dimensional combinations of atleast two chemically different materials with a distinct interface".[7]

According to McCabe: "A composite material is a product which consists of atleast two distinct phases normally formed by blending together components having different structures and properties.[8]

History[9]

1955-Michael Buonocore describes the acid etch technique, a simple method of increasing the adhesion of acrylic fillings to enamel.

1962-Rafael Bowen develops Bis-GMA, the thermoset resin complex used in most modern composite resin restorative materials.

Council on Dental Materials, Instruments and Equipment (1986): Posterior Composite Resins

In the early 1980s, short-pulsed, fiber-optic contact delivery laser technology was developed. Neodymium: yttrium-aluminum-garnet (Nd:YAG), erbium: YAG (Er: YAG), and erbium -chromium: yttrium -scandium-gallium-garnet.

UV cured composites were developed in the 1970s while light cured composites became popular in the early 1980s.

Structural Components[4]

These are highly cross linked polymeric materials which have been reinforced by glass dispersion, crystalline or resin filler particles and or short fibres that are matrix bounded by silane coupling agents.

Matrix – It is blend of aromatic or aliphatic dimethacrylate monomers such as bis-GMA, TEGDMA AND UDMA that forms continuous phase and binds the filler particles

Filler – reinforcing particles or fibres for eg Quartz, Fused silica, Aluminium silicate, Barium glasses (Fluorosilicates, Borosilicates and Aluminium silicates) Strontium glasses, Borosilicates, Lithium aluminium silicate, Pryogenic silica, Zirconium glasses and Yetterbium trifluoride.

Coupling agent – promotes adhesion between filler and resin matrix. Organosilanes such as gamma methacryloxypropyl trimethoxysilane is used most commonly.

Also contains: Inhibitor, UV absorbers, Opacifiers and Color pigments.

Recently to further enhance the esthetics, strength, durability etc, various variants of composites have been introduced such as direct composite resin, flowable composite, indirect composite resin, nanocomposites, antimicrobial composite, stimuli responsive composite, fibre reinforced composite, self healing composite etc.[10]

Flowable composites

These are low viscosity composites used since 1995.[11] Its particle size and particle size distribution is similar to the hybrid composites but with reduced filler content.[12] It has increased amount of resin to decrease the viscosity of the mixture.[13] Depending on filler content it can be used for pit and fissure sealants or small anterior restorations and can be used in conservative class I, II, III, IV, V restorations. Flowable composite is less sticky as compared to hybrid and microfills. It has good handling properties. It may be used in restoration of all tooth surfaces, all classes of restorations, direct veneers and core build ups.12 Coefficient of thermal expansion, wear rate and surface roughness is higher but has inferior physical properties. Higher CTE, greater flex and lower filler particles provide additional relief to stress. Greater film thickness act as shock absorber which alleviate negative effects of stress.[14] e.g. Flow-It (jeneric pentron), Aeliteflo (Bisco), Aeliteflo LV(Bisco), Versaflo (centrix), Tetric flow(Ivoclar), Permaflo (ultradent) and A.S.A.P Flow (DMD).[12]

Two clinical benefits:

Reduction of marginal microleakage in the short term as a result of its stress reduction by flow property and reduction of marginal microleakage in the long term because of improved durability under flexural load.[15]

Packable or Condensable composites

Dr Lars Ehrnford of Sweden in 1995 had developed this new advancement.[13] It can be used as an amalgam substitute.[16] It is marketed as composite that can be pack, carve and handle similarly as that of amalgam and also light cured in bulk upto 5µm in depth and has larger than average filler particle (15-80 µm).[17] There is slight increase in filler content and the resin matrix is adjusted to allow 1-2% higher filler content. The filler mainly consists of Aluminium oxide, Silicon oxide glass particles or barium aluminium silicate or strontium glasses.[18] Further, colloidal silica ultrafine particles are also incorporated to control the handling characteristics such as viscosity, resistance to flow, condensability and reduced stickiness.[13] The glass particles are liquified to a molten state, and it is forced through a die to form thin strands of glass fibers with a diameter of approximately 2-3 µm. These glass fibers are then reheated to an adequate temperature after pulverizing them into small space particles. As a result, glass fibers show superficial fusion at selected sites (silanation) and a 2µm dimensions continuous network of small chambers or cavities is formed. Resin is then allowed to infiltrate into these spaces or chambers.[19,20]

This concept provides a basis for fabricating packable or condensable posterior composite resin resulted in advantages of better reproduction of occlusal anatomy, better marginal adaptation, ease in achieving a good contact point.[21] It shows excellent physical properties. If proximal box is gingival, small amount of RMGI is cured and add increments of packable composite.e.g. Alert (Jeneric Pentron), Glacier (SDI), Surefill (Caulk), Pyramid (Bisco), Filtek P-60 (3M), Synergy (Coltene Whaledent), Ariston PHC (Ivoclar), Prodigy condensable (Kerr).[22]

Core buildup composite

It is tooth colored, has the ability to bond to tooth and ability to allow preparation in same appointment. It is often available in one or two shades. One shade may approximate that of dentin and one may contrast sharply for use under metals. It can be light cured, dual cured and self cured. Many adhesives show incompatibility with some of core build up materials. E.g. Ti-Core (EDS), Core paste (Den – Mat), Build – It! (Jeneric Pentron), Bis-Core (Bisco), Corestore (Kerr), Fluorocore (Caulk) and Clearfil Photo Core (J. Morita).[23,24]

Indirect composites[17,25]

To overcome the major clinical problems associated with direct posterior composite resins, the indirect composites such as inlay and onlay systems were developed. It can be used where considerable tooth structure is lost and the need of esthetic requirement and direct composite is not possible.

Advantages

Minimal wear of opposite teeth, Ability to be characterized in laboratory, Reparability with hybrids and physical properties are higher as 100% of degree of conversion.

Indications

Metal free dentistry, esthetics, decreased wear of opposing dentition (as compared to porcelain) and conservative tooth preparation

Contraindications

Long span FPD, high caries rate, opposing porcelain, bruxism, and difficult moisture control during adhesion.

Fiber reinforced composite

With the introduction of Fiber reinforced composite, a new era of restorative dentistry has been established and increase the potential use of composites.[13] These fibers can be oriented in different directions; weave type, unidirectional, mesh type, etc. in the resin matrix which improve the mechanical and physical properties of composites. The durability of the fiber reinforced composites mainly depends on essential factors including fiber loading within the resin, adhesion of fibers to the matrix, the orientation of fibers, volume of fibers in composite matrix, etc.[26] Silane coupling agents are commonly used to provide bonding between resin matrix and fibers.[27] These fiber reinforced composites have shown improved strength and stiffness and improved wear resistance. It is mainly used when high flexure strength is required. E.g. Connect (Kerr), Vectris (Ivoclar).[13]

Applications

Chairside tooth replacements (mostly single tooth), periodontal splints, fiber post for endodontic use, orthodontic retainer and space maintainers, implant prosthesis, Large span bridge ant/post, Management of cracked tooth and anchorage reinforcement in orthodontics.[13,26]

Ormocers

It is an organically modified ceramics which can be depicted as macromonomers with an inorganic silica core grafted with multifunctional methacrylate.[4] It is synthesized from multi-functional urethane and thioether(meth)acrylate alkoxysilanes as sol-gel precursors. Alkoxysilyl groups of the silane permit Si-O-Si network formation by poly-condensation reactions and hydrolysis. Size of filler particles are 1-1.5 µm and the material has filler weight of 77% and filler volume of 61%. E.g. Definite, Admira.

Advantages

Biocompatible, reduced polymerization shrinkage, high abrasion resistance, esthetically pleasing, anticaries properties, safe handling and easy manipulation, cost effective.[13,28]

Giomers[10,29]

A new hybrid aesthetic restorative material has been introduced by Shofu Inc. (Kyoto, Japan 2000) known as GIOMERS, to overcome the disadvantages of compomers which differs from both resin modified glass ionomer and composites. Giomers created a stable Glass-ionomer phase on a glass core where an acid-base reaction is induced by them between fluoride containing glass and polycarboxylic acid in the presence of water developed as Pre-Reacted Glass-ionomer (PRG)filler. The pre-reaction can involve either only the glass particles surface (known as surface pre-reacted glass ionomer or S-PRG) or almost the entire particle (known as fully pre-reacted glass ionomer or F-PRG) e.g. Reactmer (Shofu Inc, Kyoto, Japan), FL-Bond Beautifil.

It is indicated for restoring Class I - V lesions as well as for treating cervical erosion lesions and root caries. It is available in 13 shades and is supplied in syringes.

Smart Composites[30]

Smart composite was introduced in 1998 as the product Ariston pHc. It releases various ions like fluoride, hydroxyl and calcium ions as the pH drops in the area immediately adjacent to the restorative material newly developed alkaline glass filler which will reduce secondary caries formation at the margin of a restoration by inhibiting bacterial growth. The paste consists of Ba, Al and F silicate glass filler (1 µm) with ytterbium trifluoride, silicon dioxide and alkaline Ca silicate glass (1.6 Âµm) in dimethacrylate monomers: it is filled 80% by weight and 60% by volume. Order of fluoride release: conventional glass-ionomers >Smart composites> compomers.

Nanocomposites[17,31,32]

Nanoparticle filler technology gives unbeatable polish ability in a high strength, all purpose composite. New, Polycarbonate/Bis-GMA resin is not only tough, it also provides soft, sculptable handling that doesn't get sticky. Shades developed the same standards we use for our porcelain systems means reliable shade matching without a lot of fancy techniques or layering. research proven to be highly resistant to both occlusal wear and toothbrush abrasion.

The nanocomposite is composed of nanomeric particles and nanoclusters spheroidal fillers with a broad particle distribution provides a higher filler load, desirable handling characteristics, and physical properties. During abrasive wear, the nanosized primary particles in the nanocluster are suggested to wear by breaking off individual primary particles resulting in wear surfaces which have smaller defects and thus better gloss retention. It provides optimal optical characteristics since the size of the nanomeric particle is below the wavelength of light. E.g. Filtek Supreme XT.

Advantages

Superior translucency and esthetic appeal, excellent color, high polish and polish retention, Superior hardness, flexural strength and modulus of elasticity, reduction in polymerization shrinkage and excellent handling properties.

Stimuli response materials[13,33]

These are also called "smart materials". The properties of these materials essentially depend on external stimulus such as temperature, pH, mechanical stress, moisture, etc., These composite materials release fluoride, calcium, and hydroxyl ions into the surroundings of the filling depending on the pH. These materials release a significant ions when the pH is <5.5 than that at the neutral pH. Therefore, it provides additional caries protection.

Bellglass HP7,17

Belle de St. Claire in 1996 introduced Bellglass HP which is an indirect restorative material. These materials have increased polymerization rate as they are cured under pressure (29 PSI) at an elevated temperature of 1380C and in the presence of nitrogen gas. The elevated temperature and the increased atmospheric pressure not only increases the rate of curing but also reduces vaporization potential of the monomers. Due to curing in presence of nitrogen gas wear resistance is improved and additionally, the rate of curing is also improved as nitrogen gas provides an oxygen free environment. Oxygen acts as polymerization inhibitor and delays the polymerization reaction and also reduces the translucency of composites.

Self adhering composites[34,35]

Self adhering composites are also called as compo-bonds which were firstly introduced by Kerr Corp in 2009. In a single product, this composite combines the advantages of both restorative materials technologies (8th generation) and dental adhesives. Compo-bonds have the combined benefits of self etching dentin bonding agents and nanofilled resin as they eliminates the precursory bonding stage necessary to adhere, resin to tooth substrate, thus reducing the chances of postoperative sensitivity. These composites have properties similar to the conventional flowable composites. They act similarly to 7th generation of dentin bonding agents; thus, they act as shock absorbers beneath the resin based composite restoration. A longer curing time is necessary as compo-bonds function both as dentin adhesive and resin restorative both as dentin adhesive and resin restorative material, to ensure that both constitutes are fully polymerized.

Art glass[7,13]

Art glass is a nonconventional dental polymer marketed since 1999. It is widely used in making indirect restorations such as inlays, onlays and crowns. Due to the greater level of crosslinking these materials exhibit improved wear resistance and other physical and mechanical properties. The fillers used are radiopaque. Barium glass with an average particle size of 0.7µm and colloidal silica, which enhance the handling characteristics to a greater extent. For curing of these resins, a special light curing unit such as Xenon stroboscopic light curing device is used with the emission ranges from 300-500 nm. The advantages of these materials include high wear resistance compared to traditional composites, good marginal adaptation, esthetics, and superior proximal contact.

Antimicrobial materials[13,33,36]

To impart antimicrobial characteristics various antimicrobial agents and antibiotics were introduced into composites but recently, antimicrobial nanoparticles such as quaternary ammonium polyethylenimine[24,32], Silver[33-36], Zinc Oxide[37-39], Titania[40] and Chitosan[41] nanoparticles were experimented with composites to impart antimicrobial characteristics. Microbes may be killed on direct contact with these materials or through leaching of the antimicrobial materials into the oral environment. Silver and Titania particles are commonly used into dental particles to increase antimicrobial property and enhance biocompatibility.

Calcium phosphate nanoparticles[37,38]

Calcium phosphate such as Hydroxyapatite phosphate, anhydrous calcium phosphate, tetra calcium phosphate and dicalcium phosphate anhydrous have been used as fillers to make mineral releasing dental composites. Incorporating these particles will improve stress bearing capacity and ion release which inhibit dental caries.

Bioactive glass nanoparticles[39]

These have excellent regenerative properties in mineralised tissues. Dentin mineralization is accelerated due to high surface area of nanoparticles which facilitates the dissolution of ions from the gas .These nanoparticles induce the formation of apatite in dentin.

CONCLUSION

Composite is the best material for restoration but it is associated with various shortcomings that's why there is a need of continuous research for its betterment. If nanotechnology is used, new dental composites may be created and in future, other new developments in material science and biomaterials are considered in composites.

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