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RESEARCH ARTICLE

CURRENT ADVANCES IN DENTAL COMPOSITES- A REVIEW ARTICLE

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Abstract

Dental composites have almost entirely replaced amalgam restorations in the recent times. Amalgam restorations were highly un-aesthetic and toxic to the human body. Dental composites prove to be an aesthetic and biocompatible alternative to the dental amalgam. But however, composite resins present with certain limitations such as inadequate mechanical properties and wear resistance in contact areas, primarily in restorations in posterior teeth, in contrast to dental amalgam. Therefore, not entirely accepted in the dental profession, the continued advancements of composite resins have broadened the scope of acceptance into posterior restorations. This article presents a review of new age composite resins with advanced properties.

Introduction:-

"Composite" refers to a mixture. In materials science, a composite is a mixture produced from at least two of the different classes of materials, i.e., metals, ceramics, and polymers. Dental composites are complex, tooth colored filling materials composed of synthetic polymers, particulate ceramic reinforcing fillers, molecules which pro- mote or modify the polymerisation reaction that pro- duces the cross-linked polymer matrix from the di-methacrylate resin monomers, and silane coupling agents which bond the reinforcing fillers to the polymer matrix. Each component of the composite is critical to the success of the final dental restoration. However, the most significant developments in the evolution of commercial composites to date have been a direct result of modifications to the filler component.

Dental composites have been considered acceptable restorative materials for anterior applications for many years. Their tooth-matching ability and lack of metallic mercury have caused them to be promoted as an adjunct to or substitute for dental amalgam in the restoration of the posterior dentition. Though not universally accepted by the profession, the continued "fine tuning" of composite formulations by dental manufacturers has produced acceptable materials for more expanded use in the posterior dentition. These alterations have mainly involved the use of radiopaque glass fillers that are capable of being ground or formed into very fine particle sizes, thus enhancing the polish-ability and intra-oral abrasion resistance of the resultant composite. Favourable results from long-term clinical trials demonstrate that when placed correctly, composites can produce aesthetic posterior restorations with excellent longevity (el-Mowafy et ai, 1994; Taylor et al, 1994). However, there remain significant problems that limit the usefulness of these materials in the routine practice of dentistry. Although one of the concerns relates to what is perceived as a limited durability when the material is placed in occlusal contact, the most significant problems relate to the excessive contraction accompanying intra- oral polymerisation of composite. It is likely that the development of a new matrix polymer that undergoes zero or negligible curing contraction would be a major step toward solving the majority of the difficulties involved in the use of dental composite.[1]

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Classification Of Composites:

Composites may be classified as;

1) **Particle-reinforced**
- Large Particles
- Dispersion Strength

2) **Fiber-reinforced**
- Continuous (Aligned)
- Discontinuous (Short), this may further be classified as:
- Aligned
- Randomly Oriented

3) **Structural**
- Laminates
- Sandwich Panels

Composition Of Dental Composites:

Dental composites consist of the following components,

- **Resin Matrix-**

It is the phase that polymerises to form a solid mass, which bonds to the tooth structure. It's the weakest and the least wear resistant phase. It absorbs water and helps to minimise the filler content. It comprises of,

a. Bis-GMA (bisphenol-A glyceril methacrylate)
b. UDMA (urethane dimethacrylate)
c. TEGDMA (triethylene glycol dimethacrylate)

If the composite is made up of just the resin metric, it's called as Unfilled resin.

- **FILLER PARTICLES-** It is composed of,

a. Silica particles
b. Quartz
c. Glass (Ba, Sr, Zr)

If the composite is made up of the resin matrix and fillers, it's called as Filled resin. Increase in fillers, increases the mechanical properties of the dental composite.

- **Coupling Agent-**

They help to improve the physical and mechanical properties. Coupling agents form a chemical bond between the filler particles and the resin matrix, therefore inhibiting leaching by preventing water from penetrating along the resin-filler interface. Organosilane (bifunctional molecule), which is the coupling agent, its siloxane end bonds to the hydroxyl groups on filler and the methacrylate end polymerises with resin.

- **Optical Modifiers/Pigments-**

They provide the opacity or translucency which is required to make the composites similar to the natural tooth tissue. Generally, metal oxide particles such as titanium dioxide and aluminium oxide are present to provide adequate opacity or translucency.

Properties Of Dental Composite Resins

Biocompatibility

Newly placed composite resins placed in deep restorations can release chemicals that can pass into the pulp through dentinal tubules, causing an inflammatory reaction. Therefore, these tubules are required to be sealed by dentin bonding agents or protected with a base or liner. Polished composite restorations are well tolerated by the surrounding soft tissues, and very few individuals may be allergic to one or more of the components of the material.

Polymerisation shrinkage

In dental restoration, the dimensional stability of restorative materials plays an important role in the prevention of micro-leakage at the tooth-restoration interface. The restorative material must remain dimensionally stable during polymerisation and thermal and mechanical cycles. However, most composite resins do not meet this requirement, and their dimensional stability is influenced by the polymerisation reactions of the matrix. The polymerisation shrinkage of composite resins occurs following the conversion of monomer molecules to a polymer structure through the replacement of van der Waals spaces with covalent bonds, leading to a decreased free volume.[2] The polymerisation process and the magnitude of the volumetric shrinkage are influenced by the composition of the restorative material. The magnitude of this shrinkage is influenced by factors such as the curing time, high intensities of the curing light, the matrix composition, the filler content, and the concentration of photo-initiators in composite resins.[2]

Strength

Composite resin posterior restorations are influenced by mechanical properties, such as fracture toughness, compressive strength, flexural strength, wear resistance and diametral tensile strength.[3,4] The variation in strength between different composites may be explained by the differences in the chemical composition of the matrix, fillers, and filler size and distribution.[5,6] Thus, a reduction in size and increase in volume of fillers are directly proportional to an increase in compressive strength and surface hardness.[7,8]

Wear

Composite restorations tend to wear faster than amalgam restorations. Filler content in composites has a direct effect on rate of wear of composite. Composite restorations with lower volume of filler(flowable) tend to wear faster as compared to more heavily filled composite restorations. Wear of the composite restorations can result from abrasion by foods or toothbrushing. It is also caused by contact with opposing teeth during mastication or luxing.

Degree of conversion

The term 'degree of conversion' applied to resin composites, refers to the conversion of monomeric carbon-carbon double bonds into polymeric carbon-carbon single bonds. Increasing the conversion results in higher surface hardness, flexural strength, flexural modulus, fracture toughness, and diametral tensile strength. The wear resistance is also known to be increased. This improvement in its properties may be because of increased cross-linkage.[9] Composites, when photo-polymerised, exhibit an incomplete degree of conversion. Preheating the composite prior to photo-polymerisation can increase the degree of conversion. Preheating has also been shown to increase the flow and enhance the adaptation of the resin to the prepared tooth walls and, thus, potentially reduce micro-leakage.[9]

Thermal conductivity

Dental composites transmit hot and cold temperature much like the natural tooth structure. However, a low thermal conductivity is desired for a composite restoration for efficient pulp protection due to variation in temperatures. The thermal conductivity of composite is compatible with the teeth and lower than that of metal such as amalgam or gold. It is therefore biologically protective material for the dental pulp.

Water sorption

Over time, the resin matrix absorbs water from the oral cavity. This water sorption is directly proportional to the amount of resin content in the restoration. Water absorbed tends to softens the matrix which gradually degrades the material. Water also causes some hydroscopic expansion of the composite over the first week after placement.

Radiopacity

Composite resins are composed of organic resins and reinforcing inorganic particles. To make the resin portion of a composite radiopaque is challenging, as resins typically contain chemical elements with low atomic numbers, such as hydrogen, oxygen, carbon or nitrogen. For this reason, composite resin manufacturers preferred to achieve adequate radiopacity by incorporating radiopaque glass particles – such as barium, strontium and zirconia atoms, or micro-fillers containing yttrium and ytterbium – into their formulations.

Bonding To Tooth Structure:

The enamel is about 96% inorganic hydroxyapatite crystals, 1% organic material and 3% water by weight [10.] The hard tissue of dentin is about 70 % inorganic hydroxyapatite, 20% collagen fibrillar network and 10% water by weight [11]. The dentin is interlaced with tubules containing cell processes from the odontoblastic layer in the pulp. Bonding techniques must be refined to achieve strong, consistent, and long-lasting results to both surfaces. There are two goals to bonding: 1) to obtain strong retention onto the tooth structure; and 2) to maintain an impervious seal of the restoration against the tooth. Failure to maintain the seal can lead to hypersensitivity of the tooth and to recurrent decay. The retention gained by the bonding procedures may allow the dentist to retain more complex fillings with less cutting of un-decayed tooth structure.

Bonding To Enamel:

The system for bonding to enamel was developed by Buonocore in the 1950s.[12] This acid etch procedure requires the preparation of the enamel surface with an acidic solution, usually about 37% phosphoric acid. The surface then has altered surface tension and altered topography with enamel prismatic "tags" approximately 25 microns long and 5 microns apart.[10, 13] An unfilled, low viscosity resin can be allowed to flow between these tags and then polymerise to form a tight junction with the tooth enamel.[14]

The monomers used in the commercial enamel bonding systems have usually been that of the composite. Primarily the systems have been based on BisGMA with significantly larger amounts of diluents such tri-ethyleneglycol di-methacrylate.[15] Other agents could be added to further reduce the surface tension of the liquid and increase the efficiency of the flow into the enamel tags. This bonding technique offers strength of retention to the enamel[16] and significant resistance to leakage around the restoration.[17]

Bonding To Dentin:

Technology for bonding to dentin is currently going through significant changes and critical controversy. The current systems rely on a multistep procedure. Generalisation of these procedures follow.

Step 1: etch the dentin with a mild acidic solution or agent to remove some inorganic material. Such procedures produce a brush network of collagen fibers on the surface.

Step 2: a primer containing a monomer solvent system is applied and allowed to dry.

Step 3: an unfilled resin is applied to penetrate into the intricacies that have been impregnated with primer. This unfilled resin is polymerised.

The major developments in this area have been led by Bowen.[18]

The primers have contained such monomers as N- glycidyl methacrylate (NPG-GMA), and pyromellitic acid dianhydride-2-hydroxyethyl methacrylate (PMDM). Other systems include 4-methacryloxyethyltrimellitic anhydride (4- META).[19] The theory is that these primers carried in the solvent will penetrate wet dentin and produce a hybrid layer containing collagen and resin.[20] The acetone/alcohol solvent carries the monomer into the wet dentin removing the water and evaporating. This leaves a monomer impregnated collagen network that allows the resin to penetrate into the partially de-mineralisedstructure below the exposed collagen.[21, 22.]

The resin adhesive applied in the third step is primarily the enamel bonding resin systems with further modifications by such monomers as 2-hydroxyethyl methacrylate. Though there are considerable variations in the results obtained for bond strengths to dentin by many investigators, the newest systems are capable of producing bond strengths to dentin comparable to that previously obtained for enamel.[23] The ability to seal has been improved with these dentin bonding systems to the point that some are claiming complete elimination of leakage. Studies on the theory that elimination of any bacterial contamination removes any pulpal response suggest that these bioactive agents are biocompatible[.24] The stability of these bonds have as yet not been established. Earlier dentinal bonding mechanisms revealed significant failure within one year.[25]

Should these bonds prove to have a long prognosis clinically then improvements in the properties of the composite resin restorative system could make dental composite a superior direct filling material for any application in the dentition.

Advancements In Composites:

Natural Fiber Polymer Composites

The evolution of fiber composites began when scientists discovered plastics, although natural resins were used as a gluing material. During the 1900’s the synthetic plastics like vinyl, polystyrene, phenolic, and polyester were discovered. However, plastics could not meet certain applications like load transferring parts of automobiles, aircraft, sports equipment, wind turbine blades and so many; due to their low strength, therefore to enhance their properties reinforcements were introduced. The first Fiber Reinforced Composite (FRC) was developed during 1935, but the major evolution of fiber composites during World War II because of the necessity of lightweight materials. After the world war, during 1970s various resins and synthetic fibers were discovered which completely changed the conventional material usage (Tsai and Hahn, 2018; Vinson and Chou, 1975). Synthetic fibers like glass, carbon, and aramid fibers are the most common reinforcement material in the polymer composites because of their exclusive mechanical behaviour in various applications (Edie, 1993).[26]

Though synthetic fibers are attractive in their mechanical characteristics, they are non-bio degradable and create more ecological problems (Harish et al., 2009). In search of alternatives for synthetic fibers and owing to the availability, renewability, cost-effectiveness and high specific properties, the bio reinforcement natural fibers were found to be a promising replacement for the synthetic fibers in preparation of Fiber-Reinforced Plastic (FRP) composite materials (Abilash and Sivapragash, 2013; Burgueño et al., 2004).

Natural fibers possess low cost, density and weight, they are eco-friendly nature having less pollution and minimal health hazards. The natural fibers are extracted from various parts of the plants like leaves, stems, fruits and seeds. The biological, chemical, environmental, as well as economic properties of natural fibers can sufficiently improve the last properties of the fiber composites and their usage in different modern applications. The degradability of natural fibers would strongly support the recyclability characteristic of fiber composites which consequently encourage the development of NFRP (Al-Oqla et al., 2017). The density of NFRP (1.2–1.6 g/cm3) is lower than glass fiber (2.4 g/cm3), which prompts light-weight composites (Thyavihalli Girijappa et al., 2019).[26]

Polymer Rigid Inorganic Matrix Material (PRIMM)

This system is composed of a resin matrix and an inorganic ceramic component. Unlike in conventional composites; in this system, the resin is incorporated into the fibrous ceramic filler network rather than including the filler particles into the composite resin matrix. The filler mainly consists of Aluminium oxide, Silicon oxide glass particles or barium aluminium silicate or strontium glasses. Further, colloidal silica ultrafine particles are also incorporated to control the handling characteristics such as viscosity, resistance to flow, condensability and reduced stickiness.[27]

Organically Modified Ceramic Oligomers (ORMOCER)

ORMOCER is an acronym for organically modified ceramics. They are considered to be molecule-sized hybrid structures consisting of inorganic, organic copolymers. Organic reactive monomers are bound to inorganic –si-o-si-network. These molecular hybrids consist of, for example, methacrylate-terminated chains grafted on to a central cyclic poly-silioxane 2-3nm particles. These nanoparticles are dispersed on a molecular scale.[28, 29] These are high molecular weight, flexible, relatively low viscosity cross-linking molecules. The large spacing between crosslinks resulting from curing produces a low-level polymerisation shrinkage, while the inorganic network provides abrasion resistance through its glass-like structure and low water sorption due to its hydrophobicity.[28, 29, 30]

Self-Healing or Self-Repairing Composites

Materials usually have a limited shelf-life and degrade over time due to different physical, chemical or biological stimuli. But researchers have developed materials which can repair themselves. The self-healing and self-repairing composite is an epoxy-based system which contains resin-filled microcapsules. These microcapsules may be destroyed and release the resin when the epoxy resin undergoes crazing. The resin subsequently fills these cracks and reacts with a Grubb’s Catalyst that is dispersed in the epoxy composite. This may eventually polymerise the resin and repair the crack.[31]

Stimuli Response Materials

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, especially when the pH is less than 5.5, a significant number of ions than that at the neutral pH. Therefore, it provides additional caries protection.[31-33]

Conclusion:-

Due to increased demand for aesthetics by patients, dental composite hassuccessfully managed to replace amalgam as the restorative material for choice. However. it is also apparent that current formulations remain less than ideal in terms of dimensional change during curing and long-term fatigue and fracture resistance. Current dental composites have improved clinical performance in posterior restorations as compared to its previous predecessors.[1] More clinical research is required to develop new varieties of composites to combat against the existing limitations of the same.

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