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Role of Silorane composites in Dentistry- an Overview of the Composition and Properties

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Abstract

Siloranes are a class of composites introduced in dentistry, introduced by Weinmann et al in 2005. The term silorane is derived from siloxane and oxirane. The combined form of these two chemical compounds forms siloranes, which are biocompatible and hydrophobic in nature. The polymerization mechanism of silorane composites is described as a cationic ring opening polymerization reaction that causes opening and expansion of the polymeric chain. This reduces the volumetric shrinkage when compared to methacrylate based composites. This article highlights the composition and properties of silorane composites.

Keywords: *Silorane**,** polymerization shrinkage, bonding mechanism, biocompatibility.*

Introduction

For the past 30years, 80-90% of the commercial composites contain Bis-GMA monomer as the resin matrix. Dr. Ray L. Bowen in 1962 introduced methacrylate based composites. J. L. Ferracane et al 1995, modified the methacrylate based monomers by appending UDMA, TEGDMA, UTMA, BisEMA to BisGMA matrix to enhance its mechanical properties. [1] Later, Leprince et al 2010 conducted an extensive research to improve the properties of the composites. [2] Polymerization shrinkage was one of the major drawbacks in methacrylate based composites. Due to this drawback, there was various clinical challenges like 1) reduced marginal integrity 2) microleakage 3) marginal staining 4) port- operative sensitivity 5) secondary caries 6) cuspal displacement 7) formation of cracks in a healthy tooth structure. [3] The search for composites with reduced polymerization shrinkage led to the development of siloranes.

COMPOSITION:

Silorane system has been developed to minimize the polymerization shrinkage and polymerization shrinkage stress with enhanced bonding to the tooth structure. The silorane composite system consists of silorane resin, initiator and filler.[3]

SILORANE RESIN:

Silorane resin was introduced by Weinmann et al in 2005. The term silorane (3,4epoxycyclohexylsilorane) is derived from a combination of 2 chemical building blocks- siloxanes and oxiranes. Chemically siloxane is hydrophobic in nature and forms the backbone with one or more functional oxirane groups attached to it.[3]

INITIATOR SYSTEM:

Silorane composite consists of a 3 component initiator system. They are camphorquinone, iodonium salts, electron donors. Of these camphorquinone act as

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a photo-initiator which decomposes to generate free radicals on exposure to visible light with a wavelength between 430-490 nm. Iodonium salts (SbF6) are anionic and helps in enhancing the reaction. Electron donor (ethyl dimethyl amino benzoate) helps in decomposing the iodonium salts to an acidic cation thus initiating the polymerization reaction.[3]

FILLER COMPONENT:

The silorane composite consists of fine particle filler: quartz and radiopaque material like yttrium fluoride. The quartz filler particles are 0.5µm in diameter and are coated with a silane layer by the process of silanization. The silane layer helps in increasing the hydrophobic nature of the surface of filler particles; acts as an interface between filler and resin reinforcing the resin matrix and the hard filler particles, thus preventing undesired initiation of the cationic polymerization reaction by protecting them from reacting with the quartz particles.[3]

POLYMERIZATION REACTION:

The polymerization reaction of silorane occurs via a cationic ring opening reaction that reduces the polymerization shrinkage. The cationic cure starts with the activation of the initiator system which opens the oxirane ring and generates a new acidic centre. After the subsequent attraction to a new oxirane monomer, the epoxy ring is opened to form a chain. On interaction with the other monomers, a continuous network of the ring is formed. This process of cleavage and opening of the ring system gains space and counteracts the volume loss that occurs when the chemical bond is formed leading to reduced polymerization shrinkage. The most important difference is that methacrylate is cured by radical intermediates; whereas silorane polymerizes via cationic intermediates.[3]

BONDING MECHANISM:

Bonding mechanism is initiated on the application of silorane self-etching primer (SSA primer) and silorane adhesive (SSA bond). Of which SSA primer is hydrophilic that bonds to tooth structure; SSA bond is hydrophobic that bonds to the silorane composite. Silorane self -etch primer consists of 15-25% HEMA, 15-25%Bis-GMA, 10-15%- water, 10-15%- ethanol, 5-15% phosphoric acid- methacryloxy- hexyl esters, 8-12% silane treated silica, 5-10%- 1,6-hexanediol dimethacrylate, <5%- copolymer of itaconic acid, <5%- dimethyl aminoethyl methacrylate, <3% dl-camphorquinone and <3% phosphine oxide. Silorane adhesive consists of 80% substituted dimethacrylate, 5-10% silane treated silica, 5-10% TEGDMA, <5% phosphoric acid-methacryloxy-hexyl esters, 3%dl-camphorquinone, 3% 1,6- hexane dioldimethacrylate.[4]After application of SSA primer produces a mild etching and demineralization of the tooth. Bonding mechanism involves the formation of the nano-interaction zone due to acidic pH of the primer (2.7) and relatively high amount of HEMA that keeps the resin solution homogenous preventing phase separation. This is followed by the application of SSA bond that contains hydrophobic bi-functional monomers which bonds to the hydrophobic silorane resin.[3]

BOND STRENGTH:

Bond strength of composites is generally compromised due to the inhibition of free radical polymerization due to the presence of oxygen. The presence of the oxygen inhibition layer between two successive composite layers reduces the adhesion by the formation of covalent bonds with the interpenetrating network. In ring opening cationic polymerization reaction of silorane composites there is no oxygen inhibition layer formation on the polymerized surface. Bastos et al 2015, evaluated the microtensile bond strength of silorane based composite using different bonding strategies and concluded that the mean shear bond strength value for silorane composite was 27.9 Mpa [5] which was relatively greater when compared to methacrylate based composites.

PROPERTIES:

POLYMERIZATION SHRINKAGE:

Siloranes has low polymerization shrinkage due to the cationic ring opening polymerization reaction of the oxirane monomers and increased hydrophobicity due to the presence of siloxane species in its composition.[6] A study was conducted by Weinmann et al comparing the polymerization shrinkage between silorane and methacrylate based resins using Archimedes method and bonded disc method. And concluded, that silorane had the least polymerization shrinkage (0.99%) due to cationic ring opening polymerization reaction that causes the opening of the oxirane ring that gains space and counteracts the volume loss.[3]

LIGHT STABILITY:

Silorane have high ambient light stability due to the 3 part initiator system. The kinetics of reaction can be modulated by changing concentrations of three components. When compared to methacrylate based resins (2 component initiator) siloranes have high ambient light stability and light reactivity. A study was conducted by Weinmann et al on light stability inferred that the ambient light reactivity of silorane was higher (>10min) than ambient light reactivity of methacrylates (55-90sec). [3]

HARDNESS:

Guiraldo *et al* 2010 suggested that silorane based composites undergoes cationic polymerization reaction characterized by continuous ring opening expansion initiated at the time of curing which also promotes further cross-linking and hardening of the entire resin matrix than microfilled composites. The micro filled composites consist of smaller filler particles that tend to scatter light thus decreasing the effectiveness of curing light.[7] The hardness of silorane assessed by Vickers hardness test shows that it has a mean range of 73.4-82.5N/mm^2. Agarwal *et al* 2015 compared the surface hardness and depth of cure of siloranes and methacrylate based posterior composite resins in an in-vitro study and concluded that higher hardness value is present in silorane based composites than methacrylate based posterior composites.[8]

`MICROLEAKAGE/ MARGINAL QUALITY:

The bond strength and polymerization shrinkage act in the opposite direction. The low polymerization shrinkage and high bond strength leads to excellent marginal integrity of the silorane composite restoration. Silorane showed least mean microleakage score (76.82Mpa) when compared to methacrylate based composite (95.20 Mpa). Khosravi et al 2015 compared the microlekage in class-II cavities restored with methacrylate based and silorane composite at different time intervals at 24hrs, 3months and 6months. The results showed that silorane composite showed least microleakge (0.58%- 1.08%) at all the time intervals.[9]

WEAR RESISTANCE:

The wear rate of silorane was determined by three body abrasion test and was found that silorane has high wear resistance (70-80µm/ 2,00,000 rev for 1day 1.6%) than methacrylate based resins (3.5µm / after 39,000 cycles 1.0%).[10] Soliman et al 2015, evaluated the in-vitro solubility and wear rates of silorane and methacrylate composites under different pH conditions and concluded that silorane composite presented with low solubility(0.29%- 0.43%) and low wear rate (0.0005%- 0.0018%) compared to methacrylate resins. [11]

WATER SORPTION:

Water sorption leads to swelling, reduction of the mechanical properties and produces exogenic discoloration. Silorane exhibits low water sorption-6.63µg/mm^3 due to the hydrophobic nature of the resin matrix with a low tendency for extrinsic discoloration. Nanjundasetty *et al 2013* evaluated the microleakage and micro-gap formation along the gingival margin in class II cavities restored with silorane and methacrylate resins with and without flowable resin liner and inferred that siloranes showed superior marginal integrity both below and above the CEJ when compared to methacrylate-based composites.[12]

BIOCOMPATIBILITY:

Schweikl *et al* 2004 analyzed the formation of micronuclei (chromosomal aberration) and the induction of gene mutations (Hypoxanthine Phospho Ribosyl Transferaseassay) in mammalian cells. No mutagenic effects were detected for silorane composites.[13] Weinmann et al International Association for Dental Research (IADR) evaluated the DNA damage potential of silorane resin on L929 mouse fibroblast cells. Results showed that no DNA damage was produced.[3] Shafiei et al 2014 evaluated the cytotoxic effect of silorane and methacrylate based composites on human dental pulp stem cells and fibroblasts. It was concluded that compared to methacrylates, the cytotoxic effect of silorane based composite on dental pulp stem cells and dental pulp fibroblasts decreases as the time passes.

When the remaining dentin thickness is less than 1mm, the authors recommend adequate pulp protection measures.[14]

Clinical Application:

Silorane can be used as

Ø Direct posterior restorative material for class I and class II cavities

Ø Cavity liner or base.

Advantages:

Ø First composite with polymerization shrinkage less than 1%

Ø High strength and durable

Ø Low water sorption resulting in reduced exogenic staining

Ø Radiopaque

Ø Ambient light stability up to 9min

Ø Good marginal integrity and biocompatibility

Ø Easy to handle and non-sticky

Ø Excellent bond strength

Ø Minimal cuspal deformation and enamel cracks

Ø High flexural and fatigue strength

Ø Wear-resistant

Ø Natural esthetic appearance

Ø Minimal level of leachable monomers

Ø Stable in oral fluids

Ø Retention of anatomic forms

Conclusion

Silorane composites represent the next generation restorative materials that will herald a new era in restorative dentistry. This novel low shrinkage composite provides a unique combination of esthetics with superior mechanical properties comparable to clinically successful methacrylate based composites. Silorane has increased depth curve, low water sorption, high strength, reduced microleakage and good biocompatibility characteristics with low mutagenicity.

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