“Invitro Evaluation of Biocompatibility and Biomechanics of Silorane based restorative material”

ABSTRACT:

Introduction:

Composite resins, a group of esthetic restorative materials, are essential part of today’s dentistry due to its versatile clinical use and creation of invisible restorations. The present composite systems are based on methacrylate chemistry. Polymerization shrinkage (shrinkage during curing) has been one of the major drawbacks of composite resins resulting in shrinkage stress which is a challenge to the tooth-resin interface. Previously attempts have been made to reduce shrinkage by changing the filler content, amount, shape or surface treatment, or replacing other resins or modifying the resin matrix (from typical dimethacrylates monomers being replaced by methacrylates with reduced reactive group). However, shrinkage still remains an intrinsic property of composite resins, leading to failure of restorations.

A new silorane based composite, comprising of ring-opening monomer, has been introduced claiming lower polymerization shrinkage and several other promising mechanical, physical and good biocompatibility properties. Silorane-containing resins are developed by 3M-ESPE. The commercial name is Filtek P90 a low shrink posterior restorative or Filtek Silorane. This new resin chemistry has been synthesized from the reaction of oxirane and siloxane molecules and the phrase ‘silorane’ was coined (Patent Number WO98/22521; 3M ESPE Dental Products, Seefeld, Germany). The cyclosiloxane backbone imparts hydrophobicity while the cycloaliphatic oxirane sites have high reactivity and shrink less during polymerization than methacrylates. Silorane based composites (SBC) exhibit low polymerization shrinkage as compared to the methacrylate based composites (MBC).
Methodology:

The present investigation subjected SBC to a comprehensive evaluation for its biological (biocompatibility) and physical (biomechanical) properties. The cytotoxic effects on human gingival fibroblasts [HGF] and dental pulp cells [DPC] were assessed with respect to changes in proliferation and viability (MTT assay). The antimicrobial activity was evaluated against the most common oral organisms: *Streptococcus mutans* and *Lactobacillus acidophilus* (antibacterial) and *Candida albicans* (antifungal) using Agar disc diffusion method and Broth macro dilution method (MIC determination). In addition its adhesion and penetration potential on SBC were also evaluated. In analyzing certain physical properties of SBC, its fluoride and recharge ability (Fluoride sensitive ion electrode), color stability (Reflectance Spectrophotometer), surface hardness (Vickers Hardness tester), surface roughness (Surface analyzer/ profilometer), degradation resistance with respect to water sorption (WS) and solubility (SO) (weight loss or gain method) and effect of elevated temperature were studied and compared with its methacrylate counterpart MBC [Z100].

Results:

The results of the cytotoxicity assay on HGF showed that the percentage of viable cells was above 79 % in the first 24 hours and marginally decreased in 48 hours period in all groups. However, the proliferation rate was never below 84% in all the groups, at any given concentration.

DPC’s exposed to MBC showed higher viability than SBC at both the time periods tested. The results of the cytotoxicity assay showed that the percentage of viable cells was very good (>90%) in the first 24hours and significantly decreased in 48 hours period (minimum 65% in 25 µg/ml) in all concentration (p<0.05). However, the proliferation rate at any given concentration was never below 90% at 24hours for both the materials whereas it decreased below 80% at 48hours in SBC and MBC.

Agar disc diffusion method determined the antimicrobial activity of the two composites tested. Both the composite materials showed bactericidal activity against *S. mutans* and *C.
albicans but were resistance against *L. acidophilus* (no zone of inhibition). Higher antimicrobial effect was seen with SBC than MBC against both the species.

The broth macro dilution method determined the minimum growth inhibition (MIC) of 0.2µg/ml when tested against *S. mutans* and *L. acidophilus* and 1.6µg/ml when tested against *C. albicans*. Both the composites SBC and MBC showed inhibitory action against all the tested microorganisms.

The microorganisms showed more surface adherence and penetration to MBC than SBC.

For fluoride release and recharge tested, SBC and GIC showed significant increase in fluoride release from day 1 to day 7 in all materials, but showed decrease in day 14 and had marginal increase in day 30. Whereas in MBC, fluoride release gradually increased from day 1 to day 7 and then in day 14 but decreased in day 28. Comparison between immersion media (distilled water and artificial saliva) shows fluoride release was significantly greater (p<0.001) in artificial saliva than distilled water. Further, when temperature was compared, fluoride release significantly increased with temperature except in artificial saliva. The greatest re-release was in GIC > SBC = MBC. Comparison between immersion media shows fluoride re-release was significantly greater (p<0.001) in artificial saliva than distilled water for SBC and MBC. Further the difference in fluoride recharge in artificial saliva during the weekly recharge in SBC and MBC showed re-release progressively increased from week 1 to week 3. Also in comparison to individual days at the weekly recharge, day 1 showed greater release than day 3 and day 7 was least.

The SBC exhibited better color stability (less ΔE) after exposing to staining solutions. SBC showed increased discoloration from day 1 to day 28 in all fluids except cocoa, yogurt and lime. MBC had a trend of increased discoloration (p<0.05) from baseline to day 7 and then decreased to day 28. Among the staining agents cocoa was found to be least staining substance followed by lime, yoghurt, coffee, tea. The turmeric was found to be the most discoloring agent on both the composites (p<0.05). Highest discoloration was seen at day 28 (p<0.05) in almost all the staining agents. Cocoa and lime discolored the composite to maximum at early stages but remained stable thereafter. However, tea, coffee and turmeric progressively caused discoloration of the composite over time.
Among all the polishing system for SBC, Diamond bur- Astropol and Astrobursh combinations to be used. Whereas in MBC, Tungsten carbide bur - Soflex disc used showed good surface finish. SBC showed least Ra values (p<0.001) with lower surface hardness than MBC. Delayed finishing/ polishing of materials are better than immediate polishing in both the tested materials.

The SBC showed lower (p<0.05) WS and SO results than obtained with MBC. The storage in artificial saliva increased the WS and SO when compared to distilled water.

The results from the effect of temperature on SBC and MBC clearly indicate that as the temperature increases the rate of decomposition of the restorative material also increases. The change of color was the most common characteristic for each range of temperature and this was directly related with the level of carbonization and incineration of teeth.

Discussion & Conclusion:

The comparable cytotoxic nature of SBC to clinically successful MBC suggests the inert nature in the oral environment and are regarded safe. The study adds new information to our knowledge about the cytotoxic profiles of dental composite resin restorations based on different chemistries. The nontoxic nature of SBC is due to: 1. Hydrolytic stability of the material: Silorane- based composite exhibits lower solubility, water sorption and diffusion coefficients. These hydrophobic properties diminish the release of unpolymerized monomers to the oral cavity thus reducing the toxicity. 2. Lower levels of residual monomers after polymerization: Monomers released due to lower degree of conversion after incomplete polymerization, can decrease the cytotoxic effect of the composite resins. 3. Insufficient release of leachable components that produces the cytotoxicity: The low cytotoxicity does not imply absence of leached components. But, the process of leaching of toxic compounds is slow and it may not reach the lethal dose at any given time to cause the cytotoxicity in the oral cavity.

The low adhesion potential of SBC coupled with its antimicrobial property may potentially improve the longevity of direct fillings and reduce recurrent caries. This is due to the presence of yttrium fluoride (76%) in its composition and fluorides in any form have antimicrobial action. The fluoride acts to reduce the acid tolerance of the bacteria and is most
pertinent to reducing the cariogenicity of dental plaque. Also, surface roughness, surface hydrophobicity, surface free energy, water sorption influences microbial adhesion and penetration. MBC yielded highest surface roughness in comparison to SBC, due to its higher content of larger hybrid filler particles, in contrast to SBC with its microhybrid filler particles. SBC shows significantly higher surface hydrophobicity with respect to MBC resulting in reduced bacterial adhesion and penetration in the present study.

SBC had long term sustained fluoride releasing and recharging capacity, better color stability (less $\Delta E$), lower water solubility and sorption ($p<0.05$), least Ra values ($p<0.001$) with lower surface hardness and good thermal stability. The glass ionomers materials had a greater potential for fluoride release and recharge. The fluoride release and recharge of the composites was low and the values probably represented fluoride remaining on the surface after the recharge and wash cycle. In GIC, ions diffuse through a hydrogel matrix which is highly permeable whereas in composites the fluoride ions diffuse through a polymer matrix where the permeability is very slow. Re-release increased from week 1 to week 3 suggesting that topical applications of fluoride would help in prevention of caries and failure of restorations. GIC had better fluoride recharging capabilities. SBC and MBC do not significantly differ suggesting more frequent application of fluoride is needed in composites.

Highest discoloration was seen in MBC when compared with SBC with statistically significant results. MBC have higher water sorption, induces plasticization and expansion of the methacrylate polymer and have hydrophilic monomer (TEGDMA which have been reported to stain more readily) compared to SBC. The lesser filler composition of MBC also corresponds to the greater color variation observed in the present study. Hydrophobic attribute of siloxane also favors color stability and minimizes the staining in SBC.

Diamonds bur best suited for gross removal and contouring and has high cutting efficiency whereas, carbide finishing burs best suited for smoothing and finishing and has low cutting efficiency. MBC has hybrid filler which create distinctive patterns when used with diamond when compared with SBC which offers best results. Immediate finishing and polishing could cause plastic deformation (flow) of resin which is 75% cured. Thermal insults of polishing are thus created as the composite polymerization reaction would not be complete prior to 24
hours. Delaying the finishing and polishing procedure created a smoother and harder surface than immediate polishing.

SBC produced lower water sorption and solubility compared to MBC, due to its hydrophobic siloxane backbone. The study suggests that SBC composites exhibit better hydrolytic stability even after a month of water immersion compared to conventional MBC. The resistance of restoration to variable temperature is unique in itself.

The clinical significance of evaluating the fluoride release, surface hardness and roughness is not only related to the aesthetic appearance, strength and its durability but also of oral health importance, such as plaque accumulation, gingival irritation, and secondary caries. It may also be important in developing regimes for improving the delivery of topical fluoride products. The color stability of the restorative resin is of great importance to patients and clinicians when working in the esthetic zone. Dentist can select and use materials with good color stability, for excellent serviceability of the restorations. Patients can be aware of their dietary habits if their restorations needs to be worn for long period and may be advised to avoid or minimize consumption of those beverages during the service of the composite restorations. Resistance to degradation in the oral environment is an important prerequisite for the clinical longevity of composite restorations. Chemical degradation of the restorative materials (excessive sorption and solubility) can have deleterious effects on the mechanical and physical properties. The effect of elevated temperatures on the restoratives would be used as valuable tool in identification process in forensic odontology for the identification of burnt victims. Clinicians will have an informed understanding of the advantages and limitations of alternative materials for specific environmental circumstances. These finding highlighted that SBC may enhance clinical integrity and reduce marginal leakage leading to improved restoration longevity.