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COMPARISON OF MICROLEAKAGE AND MICROSHEAR BOND STRENGTH OF A LOW SHRINKAGE COMPOSITE VERSUS METHACRYLATE BASED HYBRID COMPOSITE- AN IN VITRO STUDY

Dental Science

Dr. Anupreeta. A*	Reader, MDS In Conservative Dentistry And Endodontics, GITAM Dental College And Hospital, Rushikonda, Visakapatnam *Corresponding Author
Dr. T.Rambabu	Professor And Head Of The Department, MDS In Conservative Dentistry And Endodontics, Drs.Sudha & Nageswara Rao Siddhartha Institute Of Dental Sciences, Gannavaram-521 286
Dr. Girija S Sajjan	Professor And Head Of The Department, MDS In Conservative Dentistry And Endodontics, Vishnu Dental College,Vishnupur,Bhimavaram 534 202
Dr. V R K R R Manikya Kumar	Reader, MDS In Pedodontics And preventive Dentistry GSL Dental College, Rajahmundry – 533294
Dr. Ravi Kumar Konagala	Senior Lecturer, MDS In Conservative Dentistry And Endodontics, GITAM Dental College And Hospital, Rushikonda, Visakapatnam - 530045
Dr. Mohan RB	Reader, MDS In Conservative Dentistry And Endodontics, GITAM Dental College And Hospital, Rushikonda, Visakapatnam – 530045

ABSTRACT

Purpose of the study: was to evaluate and compare, microleakage and micro-shear bond strength of low shrinkage novel composite [Silorane Filtek™ P90] with that of conventional hybrid composite FILTEK™ Z250.

Methodology: For microleakage evaluation, standardized Class V cavities on extracted premolars were randomly assigned into 2 groups (n=10); Gruop 1= FILTEK™ P90, Gruop 2= FILTEK™ Z250. Restored specimens were thermocycled and subjected to methylene blue dye penetration following which, they were sectioned. microleakage was evaluated steromicroscopically and data was statistically analyzed using the Mann whitney test. For micro-shear bond strength test, flat dentinal surface of 2 test groups(n=10) specimens were restored to create microcylinders and were then subjected to micro-shear bond strength test at cross-head speed of 0.5 mm /min. The results were statistically analysed using Unpaired t test.

Results: Group1 exhibited significantly decreased microleakage at cemental margin, as compared to Group 2. At enamel margin, there was no statistical significance. In terms of overall microleakage, Silorane showed statistically significant lower values. The micro-shear bond strength of Group1, was significantly higher, compared to Group 2.

Conclusion: Silorane composite Filtek™ P90 showed decreased microleakage and higher bond strength than Filtek™Z250.

KEYWORDS

Microleakage, Micro-shear bond strength, Resin based composites (RBCs).

Introduction

The durability of a restoration is largely based on maintenance of the tooth/restoration interface which should resist dimensional changes to prevent microleakage and possible further deterioration of the restoration. With the advent of adhesive dentistry, composites have become the material of choice in restorative dentistry, especially due to their esthetic properties, the adhesive concept and patient demand.

Significant improvements have been made since the pioneering work of R.L. Bowen and the introduction of composites in 1960s. Despite significant advances in the mechanical and physical properties of modern composites, two major shortcomings that still have to be overcome are polymerization shrinkage and the resulting shrinkage stresses which challenge the tooth/composite interface.[1,2,3]

The polymerization of conventional dental composites is accompanied by a volumetric contraction, usually in the range of 1.5%–5%, resulting in the development of internal stresses (Ferracaine et al 2005)[3] which when exceeds the bond strength, results in loss of adhesion, marginal failure, subsequent secondary caries, marginal staining, restoration displacement, tooth fracture, and/or post operative sensitivity. These represent the most important reasons for the replacement of existing insufficient composite restorations .[4,5,6]

Previous studies have demonstrated that etched and bonded enamel produces a more consistent seal as compared to that of dentin. Dentinal adhesion is more complicated because of the composition and histologic structure of the substrate which is responsible for inconsistent bond strengths and marginal leakage, which still occur with all resin-based adhesives[7].

Taking into consideration all these factors a composite with low shrinkage potential is highly desirable. Various material modifications have been developed to address the problem of polymerization shrinkage and stress. However so far no adhesive restorative technique is available that guarantees a reliable marginal adaptation bond when margins are located in cementum/dentin.

In this regard novel composites were introduced which claims to stand for their low shrinkage potential and polymerization stress. Filtek™ P90 was one such composite system deriving its name Silorane, based on the Silorane monomer chemistry which polymerizes via photo cationic ring-opening reaction,of oxirane and siloxane molecules resulting in a lower volumetric shrinkage of the composite below 1 vol%[1,2].

This study aimed to investigate the role of this novel composite in improving marginal integrity by assessing the microleakage and micro-shear bond strength parameters of silorane composite in comparison to a commonly used conventional hybrid resin composite (Filtek™ Z250). The low shrinkage potential of silorane composites could provide a solution to the common clinical failure of composites owing to bond failure and ensuing microleakage at the margins of restorations. The null hypothesis tested was there would be no significant difference in the microleakage and micro-shear bond strength parameters of the two tested materials.

Materials& Methods:

40 sound premolar teeth free from caries, coronal fractures or cracks or abrasions which were extracted for periodontal and orthodontic reasons were selected for this study. 20 specimens each (n=10) were separately utilized for microleakage and micro-shear bond strength test respectively.

Microleakage:

Standardized class V cavities of dimensions 3 X 3 X 1.5 mm were prepared on the buccal surface of teeth with a high speed airotor handpiece using a number 245 tungsten carbide bur ensuring that the coronal margin of the cavity lies in enamel and cervical margin in the cementum. Positions of cavities were standardized using an acrylic resin template template of dimensions (3 X 3 mm) .The teeth with prepared cavities were then randomly divided into two groups of 10 each (n=10). Group 1 restored with FILTEK™ P90 and Group 2 restored with FILTEK™ Z250

The composition of the materials and the dentin bonding systems used in the present study are enlisted in Table 1. The corresponding adhesive systems were applied to the cavity walls according to manufacturer instructions (Table 2) for each group.

Table 1 :Specification,Composition ,Manufacturers for Materials used in the study.

Group	Material	Specification	Composition	Manufacturer
I	**Filtek™ P90**	Visible light activated Silorane based restorative composite	Silorane resin, Initiating system: camphorquinone, iodonium salt, electron donor Fillers: Quartz filler,Yttrium fluoride with Average Particle Size (μm) 0.47 Stabilizers, Pigments	3M ESPE Dental Product St. Paul, MN,USA
	Silorane Adhesive Bond System	Silorane Self-etch Primer:	Phosphorylatedmethacrylates Vitrebond copolymer BisGMA , HEMA Water,Ethanol Silane-treated silica filler : 7 nm	3M ESPE Dental Products St. Paul, MN, USA
		Silorane Adhesive Bond	Photoinitiator : Camphorquinone ,Stabilizers	
			Hydrophobic dimethacrylate Phosphorylated methacrylates TEGDMA Silane – treated silica filler Photoinitiator : Camphorquinone, Stabilizers	
II	**Filtek™ Z250**	Visible light activated methacrylate-based restorative composite	Bis-GMA and TEGDMA resins.filler is zirconia/silica. Additional contents: stabilizers, catalysts and pigments	3M ESPE Dental Products St. Paul, MN, USA

Table 2: Application of bonding agents.

Adhesive system	Manufacturer instructions
Silorane Adhesive Bond System	Apply the Silorane self-etch primer using minisponge applicator, rub gently for 15 seconds, then air-disperse carefully followed by light curing for 10 seconds. Silorane adhesive was then applied similarly followed by light curing for 10 seconds
Clearfil SE Bond	Apply Clearfil SE Bond Primer and agitate for 20 seconds .then air dry Apply Clearfil SE Bond Adhesive air-thin and light-cure for 10 s

Both groups1 and 2 were restored with the respective restorative material, and light cured using a light curing unit (QTH 3M-ESPE™ XL2500,850 Mw/cm ^{2}, USA) according to manufacturer's instructions. The restored teeth were preserved in thymol containing distilled water for 24 hours and then thermocycled for 100 cycles between 5 ± 2^0C and 55 ± 2^0C with an immersion time of 30 seconds and transfer time of 5 seconds. The apices of the teeth were sealed with sticky wax and were coated with double layer of nail varnish except for 1 mm around margins. After drying all the teeth were immersed in 1% methylene blue dye solution for 24 hours. Then specimens were sectioned longitudinally in a bucco-lingual direction using a diamond disc. The sectioned teeth were observed under stereomicroscope (Olympus SZ, Tokyo,Japan)at 16 X magnification and microleakage was assessed based on the following scoring criteria given by Khera and Chan[8] as shown in the Table 3 .

Table 3: Scoring criteria -Khera and Chan.

SCORE	DYE PENETRATION
0	No leakage
1	Less than and upto one half of the depth of the cavity preparation was penetrated by the dye
2	More than one half of the depth of the cavity preparation was penetrated by the dye but not upto the junction of the axial and occlusal or cervical wall
3	Dye penetration was upto the junction of the axial and occlusal or cervical wall but did not include the axial wall
4	Dye penetration including the axial wall.

The assessment was done separately to compare a) microleakage at enamel b) microleakage at cemental margins c) overall microleakage.

Micro shear bond strength:
Twenty sound premolar teeth stored in thymol containing water immediately after extraction, were used in the study within 30 days with the water being changed every two days. The roots of the teeth upto 1 mm below the cemento-enamel junction were embedded in acrylic blocks using cylindrical aluminium molds of 2 cm height. A flat uniform dentinal surface was prepared on the buccal aspect of the teeth. The samples were then randomly divided into 2 groups (n=10), according to the restorative material used (Group 1) FILTEK™ P90 and (Group 2) FILTEK™ Z250.

Bonding procedures:
Group 1: (Silorane Adhesive Bond System) Silorane self-etch primer was applied to the dentinal surface using the sponge applicator, rubbed gently for 15 seconds, then air-dispersed carefully. This was followed by light curing for 10 seconds. Silorane adhesive was then applied similarly.

Group 2: (Clearfill SE) self-etching primer agent was applied using a sponge, agitated for 20 seconds. After air-drying, the bonding agent of the corresponding adhesive was applied.

Prior to irradiation of the bonding agent of both groups, custom made polyvinyl siloxane mold of (1 mm inner diameter and 2 mm length) was placed perpendicular to the buccal surfaces of all the prepared samples and photo irradiated for 10 sec following which the corresponding restorative material was carefully condensed into the tube and cured for 40 seconds using a light curing unit (QTH 3M-ESPE™ XL2500,850 Mw/cm ^{2}, USA). The mold was carefully removed using a scalpel blade after 1 hour. The specimens of both groups were stored at 37 ^{0}c for 24 hours in distilled water and were then subjected to the micro-shear bond testing.

Micro-shear bond strength testing
For the micro-shear test the samples were mounted on Instron Testing machine and sheared at the tooth restoration interface at a cross-head speed of 0.5 mm per minute until fracture. The Dentin shear bond strengths obtained were converted to MPa (MegaPascal) and the results were statistically analysed using unpaired t- test.

Statistical analysis
All the data were gathered using statistical package for social sciences (SPSS) Version 16. For microleakage evaluation the assessment was done separately to compare (a) microleakage at enamel (b) cemental margins (c) overall microleakage. The mean microleakage scores were calculated for each group by Mann-Whitney test for inter-group comparisons. (The level of significance was set at $P < 0.05$).

The data pertaining to the micro-shear bond strength test was subjected to statistical analysis using the unpaired t test. (The level of significance was set at $P < 0.05$)

Results
The present study showed statistically significant difference in the microleakage and micro-shear bond strength parameters of the two tested materials .Thus the null hypothesis was rejected.

(a) At enamel margins there was no statistically significant difference (p=0.28) in the mean microleakage values between the groups, with group 1 demonstrating a mean microleakage value (1.1 ± 0.3) which was lower than that of group 2 (1.5 ± 1.0), as depicted in Table 4.
(b) At cemental margin there was a statistically significant difference (p = 0.02) between both the groups, with group 1 demonstrating a lower mean microleakage (1.4 ± 1.0) than that of group 2 (2.3 ± 1.1), as depicted in Table 5.

Table 4: Comparison of enamel Microleakage scores between two groups.

Margin	Groups	No.	Microleakage Scores			Gr.1 V/s Gr 2
			Range	Mean±SD	Median	
Microleakage at enamel margin	Gr. 1	10	1 – 4	1.1±0.3	1	P = .28
	Gr.2	10	1 – 4	1.5±1.0	1	

P < 0.05, statistically significant

Table 5: Comparison of Cemental Microleakage scores between two groups.

Margin	Groups	No	Microleakage Scores			Gr.1 V/s Gr 2
			Range	Mean±SD	Median	
Microleakage at cemental margin	Gr. 1	10	1 - 4	1.4±1.0	1	P = 0.02
	Gr.2	10	1 - 4	2.3±1.1	2	

P < 0.05, statistically significant

(c) In terms of overall mean microleakage, there was a statistically significant difference (p = 0.02) between both the groups, with group 1 demonstrating a lower mean microleakage (1.4 +1.0) than than that of group 2 (2.3 + 1.1), as depicted in Table 6.

Table 6: Comparison of overall Microleakage scores between two groups.

Margin	Groups	No.	Microleakage Scores			Gr.1 V/s Gr 2
			Range	Mean±SD	Median	
Overall microleakage	Gr. 1	10	1 - 4	1.4±1.0	1	P = 0.02
	Gr.2	10	1-4	2.3±1.1	2	

P < 0.05, statistically significant

Micro-shear bond strength

The present study showed statistically significant difference between both the groups with group 1 demonstrating a higher mean bond strength (22.78 ± 8.75) value as compared to that of Filtek™ Z250 ((11.43 ± 7.03), as depicted in the Table 7.

Table 7: Comparison of Micro Shear Bond strength between two groups.

Groups	No.	Micro shear Bond strength (Mpa)				Gr.1 v/s Gr.2	
		Mean	SD	Min.	Max	t value *	P level
Gr. 1	10	22.78	8.75	13.89	38.81	3.20	0.005, Sig (P < 0.01)
Gr. 2	10	11.43	7.03	2.23	21.63		

Discussion

The damaging effects of polymerization shrinkage and stress may be minimized through modified clinical techniques and advances in material science. However, the clinical methods used to minimize polymerization shrinkage can be time-consuming, and some of the procedures remain unproven or controversial.[3,9,10] The other approaches involve modifications of formulation of the material such as an increase in the filler content, an increase in molecular weight per reactive group and the use of ring opening monomers known for their low polymerization shrinkage[9,10].

Moszner et al[11] introduced vinyl cyclopropane derivates as radical curing ring opening monomers. Smith and co workers[12] focused on the use of cationic ring opening spiro-ortho carbonates especially in combination with epoxy monomers. Although such experimental resin based composite systems showed promising mechanical properties, the slow development of flexural strength coupled with cytotoxicity and mutagenic concerns of oxirane based resin blends and the fact that these exhibited incomplete ring opening and minimal co-polymerization which resulted in a minimal reduction of shrinkage[13] prompted research into the development of an alternative class of ring-opening monomers .

Guggenberger and Weinmann[1] have proposed an oxirane-based resin formulation that may potentially overcome the disadvantages of previous low-shrinkage oxirane-based RBCs. The novel resin chemistry has been synthesised from the reaction of oxiranes and siloxane molecules and termed 'silorane' and is reported to have decreased polymerisation shrinkage(< 1 %), increased hydrophobicity and improved biocompatibility compared with conventional methacrylate based restorative materials .[1,12,13,14,15]

Thus this study was aimed to investigate whether the low polymerization shrinkage of this novel composite would favorably affect clinical parameters such as microleakage and micro-shear bond strength in comparison with a conventional composite.

The most effective method for evaluating the seal of restorative materials to cavity walls is by microleakage studies. Kidd[6] defined microleakage as the clinically undetectable passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material. To evaluate the relevance of a leakage test, the effective size of oral bacteria must be considered. Because of the range of bacterial sizes (0.5- 1 μm), dyes such as methylene blue and basic fuchsin, silver nitrate are realistic agents to identify the presence of a clinically relevant gap of 0.5-1 um. Since the ions of dyes are of a smaller size with the smallest being (120 nm) similar to dimensions of bacterial toxins, therefore they are more penetrative and hence act as an effective testing agent by allowing its ingress through micro crevices at the tooth composite interface[5,16].

Thus in the present study 1% methylene blue was opted which is considered an acceptable technique as previously used in the literature.[10,17] A Class V cavity design was selected for the current study by taking into consideration the following factors suggested by Von meerbek et al[18]. Class V cavities do not provide any macro-mechanical retention, so that ineffective bonding will result in early restoration loss, their margins are located in enamel/dentin as well as in cementum/dentin, their preparation and restoration is minimal, relatively easy, thereby somewhat reducing practitioner variability, and they have an unfavourable C factor ratio that causes greater polymerization stress as a result of restoration contraction by the bonded surface.

In the present study when comparing the microleakage of test groups at enamel margin no statistically significant difference in microleakage was observed among the groups. However at cemental margin and in terms of overall mean microleakage, Filtek™ P90 silorane demonstrated lower microleakage than that of Filtek™ Z250 with a statistically significant difference. The reason for this difference between gingival and enamel leakage score is attributed to the fact that bonding to dentin and cementum is more technique and substrate sensitive than bonding to enamel. The leakage observed at cervical margins may be related to the absence of dentinal tubules in the limiting 100 μm of cervical margin and the relatively low number of tubules in the first 200-300 μm of the gingival floor and the organic nature of the dentin substrate [7,19]. The results of this study are in accordance with other microleakage studies [10,13,20] which also demonstrated lesser microleakage of Silorane composites. Krifka *et al* compared marginal integrity of Class V cavities restored with Filtek Silorane composite and methacrylate composite restorations and concluded that initially and after themocycling, the silorane system showed statistically better marginal integrity on both enamel and dentin than the methacrylate system[21]. Kermanshah et al evaluated the effect of cyclic loading on the microleakage of Filtek P90 compared with low shrinkage methacrylate-based composites in class V cavities and they concluded that Filtek P90 exhibited low shrinkage at gingival margin. Significant difference in gingival microleakage was found between Aelite and Filtek P90 in their study[22]. Joseph A et al compared the microleakage in Class II box preparations with the gingival margin above and below the cemento-enamel junction (CEJ) restored with Silorane composite and methacrylate composite using two different layering techniques and results showed that Silorane composite had significantly lesser microleakage[23]. Bogra P et al also compared microleakage in class II cavities restored with a nanoceramic restorative (Ceram X) and a silorane composite (Filtek P90) and reported that Filtek P90 showed better sealing ability than Ceram X both above and below the CEJ[24].

Based on the results of the present study we could correlate that the lesser microleakage of silorane composites was owing to its unique "ring opening" monomers which connect by opening, flattening and extending towards each other resulting in significantly less volumetric shrinkage (<1 %) as cited in literature.[1,2,12,14,25,26,27.]

With regard to bond strength, achieving a strong and durable bond between adhesive resins and dental substrates is of critical importance for the longevity of bonded restorations. Until the mid-nineties, shear and tensile bond strength tests were performed exclusively in specimens with relatively large bonded areas, usually 3–6mm in diameter (approximately 7–28 mm^2) because they were easy to perform, requiring minimal equipment and specimen preparation. However, the validity of expressing bond strength in terms of nominal (i.e., average) stress has been questioned due to the heterogeneity of the stress distribution at the bonded interface. The need for new methods to overcome these limitations led to the use of specimens with small bonding areas (*i.e*., below 2 mm^2), in the so-called micro-tensile and micro-shear tests.[28,29] The small size of the specimens led to a more favorable stress distribution and thus failure, representing the true ultimate strengths.[23] Sano et al 1994[30] introduced the microtensile bond test which was widely adopted. However it is associated with a higher number of pre-testing failures [18]. In 2002 the micro-shear bond test was developed by Shimada et al[31] as an alternative to the microtensile test and was used for the present study as it was considered more useful in terms of the test requiring less laborious procedure during specimen production, the bond test areas can be much better controlled by the use of known diameter microbore tubing and the micro-shear test requires use of lesser material and fewer teeth.[29,31]

Current literature showed paucity of data regarding micro shear bond strength testing of silorane composites which was also another factor for evaluating the micro-shear bond strength of this novel composite. In the present study, Filtek silorane demonstrated higher mean bond strength compared to that of Filtek Z250 and was statistically significant. Sharifi et al compared micro-shear bond strength between silorane-based composite and conventional methacrylate based composite to the dentin of primary teeth and according to their results, silorane-based composite (P90) has higher micro-shear bond strength to the primary dentin compared to the methacrylate-based composite (Z250)[32]. According to De Munck et al and Van Ende et al high micro shear bond strength of P90 composite is attributed to P90 adhesives, which provide nano-interaction to dentin and also provide potential for additional primary chemical interaction with hydroxyapatite that remained available at the dentin interface, thereby contributing to good bond strengths[33,34].

Conclusion

In conclusion, within the limitations of this study, low shrinkage silorane composite (Filtek™ P90) performed significantly better than conventional hybrid composite (Filtek™Z250) in terms of overall microleakage, microleakage at cemental margin and microshear bond strength. However, long term in-vivo trials and laboratory evaluations should be conducted to draw clinically relevant conclusions about its potential in contributing to improved restoration longevity.

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