Original Article

A Comparative Evaluation of Microleakage among Newer Composite Materials: An *in vitro* Study

Abstract

Background: Good adhesive bonding of restorative materials to cavity walls minimizing microleakage is an important criterion for the performance and longevity of a restoration in the oral cavity. The present study is aimed to compare the microleakage among newer composite materials. **Materials and Methods:** Forty-five extracted healthy premolars were collected; standard Class II cavities were prepared. They were randomly divided into three groups of 15 teeth each. The groups were made based on the different composite restorative materials used for restoration. Group A consisted of conventional microfilled composite resin restorations, and Group B was posterior nanocomposite resin. Group C was restored using ORMOCER – Admira. After completion of restorations, all teeth were subjected to thermocycling at 5° C, 37° C, and 55° C for 250 cycles. Later, all samples were immersed into 50% silver nitrate dye group wise for for 4 hours (h), and teeth were sectioned buccolingually. Sectioned teeth were observed under a stereomicroscope for the evaluation of microleakage. ANOVA and unpaired *t*-tests were used for statistical analysis. The significance level was at set $P < 0.001$. **Results:** The results of this study showed that Group C (ORMOCER – Admira) presented with the least microleakage followed by Group B (Tetric N-Ceram) followed by Group A (Tetric Ceram). **Conclusions:** Overall ORMOCER – Admira performed better than the other two composite materials with the least microleakage.

Keywords: *Dye penetration, microleakage, nanocomposites, newer composite materials, ORMOCER research*

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Introduction

Over the past 50 years, changes have occurred in the development of restorative materials. Adherence of restorative material to cavity walls is an important criterion for its performance and longevity in the oral cavity. Microleakage is "clinically undetectable passage of bacteria, fluids, molecules, or ions between cavity walls and the restorative material applied to it."[1] It causes hypersensitivity, tooth discoloration, recurrent caries, pulpal injury, and deterioration of restorative material. Composite restorations have proved to be good; however, microleakage is still a problem. Newer composites have evolved showing less microleakage.

The study has been carried out to comparatively evaluate microleakage among newer composite materials.

Materials and Methods

The study was conducted in the Department of Pediatric and Preventive Dentistry, Institute of Dental Sciences, Bareilly. Forty-five healthy premolars extracted for orthodontic reasons were used in the study [Figure 1a]. The teeth were stored in normal saline before cavity preparation. Standard Class II cavities were prepared with the following dimensions: occlusal depth – 1.5 mm, occlusal width – 2 mm, width of proximal preparation – 3 mm, location of gingival cavosurface – 1.5 mm occlusal to cemento-enamel junction, width of gingival floor – 1.5 mm, and depth of axial wall – 3 mm. Prepared cavities were checked with the help of a calibrated Williams periodontal probe and metallic scale. The prepared teeth were divided into three groups based on the restorative material used as follows: Group A – conventional microfilled composite (Tetric Ceram) + Tetric N Bond,

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Group B – nanocomposite (Tetric N-Ceram) + Tetric N Bond, and Group C – ORMOCER (Admira-Vocodent) + Admira Bond [Table 1]. Each group contained 15 teeth.

The sample teeth of each group were thoroughly dried and restored with the respective restorative materials using Teflon-coated instruments, cured incrementally, polished, and finished as per the manufacturer's instructions [Figure 1b].

The restored teeth were placed in three different Petri dishes group wise and subjected to thermocycling at 5° C, 37° C, and 55° C, 250 cycles [Figure 1c]. After thermocycling, apices of each tooth were sealed with clear self-cure acrylic resin, and the whole specimen was coated with nail varnish expect for the area of restoration and 2 mm from the periphery of the restoration [Figure 1d]. This procedure was repeated for all 45 restored teeth, followed by immersion of the sample teeth group wise into freshly prepared 50% silver nitrate solution for 4 h in a dark room [Figure 2a]. Later, the excess dye was washed off, and samples were again immersed group wise in freshly prepared X-ray developer solution exposed to 200 watts light bulb for 4 h [Figure 2b]. Later, the teeth were removed from the solution and gently rinsed under running water. The teeth were then sectioned buccolingually and observed under the stereomicroscope (×10 resolution-Trinocular research microscope – Kyowa) to evaluate the depth of dye penetration.

Figure 3a shows microscopic dye penetration in Group A sample, Figure 3b shows dye penetration in Group B sample, and Figure 3c shows dye penetration in Group C sample.

A computer software (Dewinter Biowizard 4.1) was used to assess the depth of dye penetration. The method followed was similar to that of Simi and Suprabha and Hilton *et al*.[2,3]

Statistical analysis

The data obtained were tabulated and subjected to statistical analysis. ANOVA and unpaired *t*-tests were used. The significance level was at $P < 0.001$.

Results

The depth of dye penetration of each slice was recorded, and mean was obtained which was used in statistical analysis.

The comparison was done between the mean dye penetrations of Group A and Group B, and it was found that Group A showed greater dye penetration than Group B, indicating increased microleakage with Group A [Table 2]. Group B showed greater dye penetration than Group C [Table 3], and when the means of Group A and Group C were compared, Group A exhibited greater dye penetration [Table 4]. All the values were statistically significant.

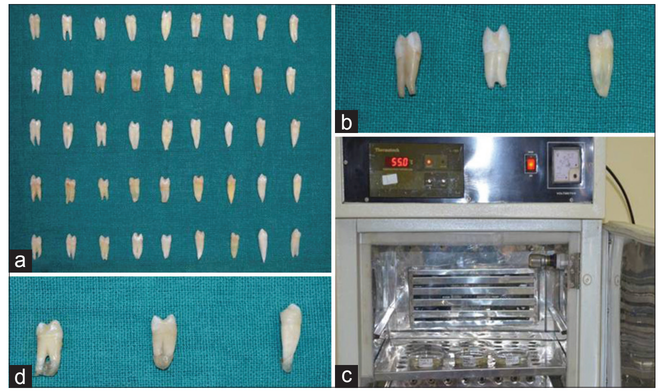


Figure 1: (a) Forty-five extracted human premolars; (b) teeth after restoration; (c) samples in thermostat; and (d) apical seal with acrylic and varnish application

Figure 2: (a) Samples in silver nitrate dye and (b) samples in developing solution

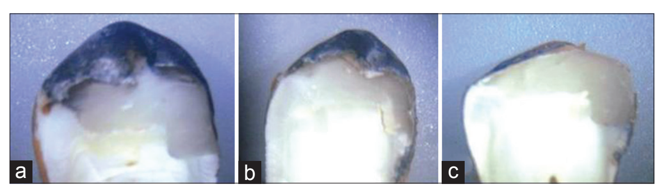


Figure 3: (a) Microscopic dye penetration in Group A; (b) microscopic dye penetration in Group B; and (c) microscopic dye penetration in Group C

The intergroup comparison between all the three groups together showed that mean dye penetration values in Group C – ORMOCER (Admira) were least in comparison to Group B – nanocomposite (Tetric N-Ceram) and Group A – conventional microfilled composite (Tetric Ceram) which was statistically significant [Table 5 and Graph 1].

Discussion

Recent advances in restorative materials as well as increased demand for esthetics have led to the development of several

Table 1: Details of the three material groups used in the study

Groups	Etchant used	Bonding agent (cured - 20 s)	Restorative material	Curing time
Group A Tetric Ceram (*n*=15 teeth)	N - Etch Ivoclar - Vivadent 15 s	Tetric N bond (total etch)	Tetric Ceram (Vivadent)	60 s each increment
Group B Tetric N Ceram (*n*=15 teeth)	N - Etch Ivoclar - Vivadent 15 s	Tetric N Bond (total etch)	Tetric N Ceram (Vivadent)	60 s each increment
Group C Admira (*n*=15 teeth)	Vococid - Vocodent 15 s	Admira Bond (Vocodent)	ORMOCER (Admira)	60 s each increment

Table 2: comparison of dye penetration (in mm) between Group A (Tetric Ceram) and Group B (Tetric N Ceram)

Material	*n*	Depth of Dye penetration (mm) [Mean±SD]	Mean difference (mm)	'*t*'	*P*
Group A	15	0.5566±0.2014	0.3333	5.827	<0.001*
Group B	15	0.2233±0.0922			

SD=Standard Deviation. *Value of Significance

Table 3: Comparison of dye penetration (in mm) between Group B (Tetric N Ceram) and Group C (Admira)

Material	*n*	Depth of Dye penetration (mm) [Mean±SD]	Mean Difference (mm)	'*t*'	*P*
Group B	15	0.2233±0.0922	0.1854	7.238	<0.001*
Group C	15	0.0379±0.0366			

SD=Standard Deviation. *Value of Significance

Table 4: Comparison of dye penetration (in mm) between Group A (Tetric Ceram) and Group C (Admira)

Material	*n*	Depth of Dye penetration (mm) [Mean±SD]	Mean Difference (mm)	'*t*'	*P*
Group A	15	0.5566±0.2014	0.5187	9.814	<0.001*
Group C	15	0.0379±0.0366			

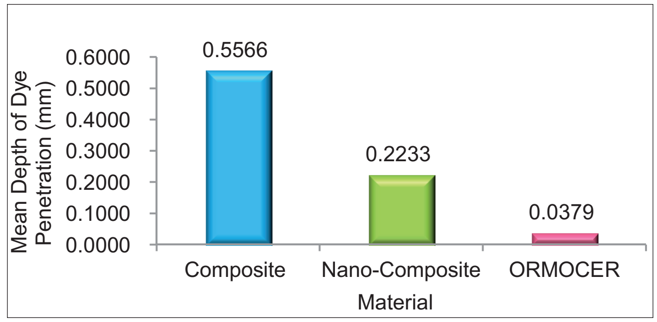
SD=Standard Deviation. *Value of Significance

Table 5: Means of depth of dye penetration (in mm) for all the three material groups

Material	*n*	ANOVA		
		Range (mm)	Mean±SD (mm)	*F* statistic and Significance value
Group A	15	0.1430-0.8610	0.5566±0.2014	*F*=61.671; *P*<0.001*
Group B	15	0.0880-0.3830	0.2233±0.0922	
Group C	15	0.0010-0.1040	0.0379±0.0366	

F statistic=Variation between Sample means in ANOVA. *Value of Significance

restorative materials. In spite of the marked development in the resin composite restorative material technology, there are reports of clinical failure of these restorations. The integrity and durability of the materials are dependent on the marginal adaptation to the cavity walls which contribute to the clinical performance and longevity of restoration in the oral cavity. Improper marginal seal leads to microleakage at tooth-restoration interface resulting in



Graph 1: Mean depth of dye penetration (mm) in three groups (*N*=15)

failure of the restoration. Microleakage is mainly attributed to the polymerization shrinkage occurring in resin-based materials. Posterior resin composite shrinks between 2.6% and 7.1% by volume.[3] The extent of shrinkage depends on the molecular weight of the monomer, the filler load, and the treatment technique of filler particles. The relationship between marginal leakage of the restoration and type of restorative material has been extensively studied. The type of restorative material is partly determined by amount of filler particles. More filler particles increase the strength and modulus of elasticity and reduce polymerization shrinkage. Shrinkage can be reduced by decreasing the filler size. Polymerization shrinkage creates significant stress in tooth structure leading to bond failure in spite of a good adhesive system.[4]

Hybrid composites due to their large-sized filler particles show increased monomer elution and increased polymerization shrinkage.[5] Although they are esthetically acceptable, they have high failure rates and this led to the search for newer materials with reduced polymerization shrinkage and minimizing microleakage.

The new generation materials include nanocomposites and ORMOCER.[6,7] Nanocomposites were formulated by top-down approach, to make the filler particles of one nanometer in diameter. Due to this, nanocomposites show reduced polymerization shrinkage and low microleakage, thereby making them superior to composite resins. ORMOCER was developed by Fraunhofer Institute in cooperation with dental industry in 1998. It basically consists of three components organic polymers, inorganic components, and polysiloxanes. Organic polymers influence the polarity and the ability to cross-link. The glass and ceramic components are responsible for thermal expansion and chemical stability. The polysiloxanes influence the elasticity, interface properties, and processing. The inorganic components in ORMOCER are bound to the organic polymers by multifunctional silane molecules. Therefore, after polymerization, the organic portion of methacrylate forms a three-dimensional network resulting in reduced polymerization shrinkage when compared to conventional composites. The volumetric shrinkage of ORMOCERs was reported to be <2%, thus indicating a better marginal integrity.[6-10]

The coefficient of thermal expansion of restorative materials is different from the tough tooth structure. The restoration tends to expand and contract more than enamel and dentin when subjected to temperature changes in the mouth, thus increasing the interfacial gap leading to microleakage.[11,12] Therefore, thermocycling of the specimen was done to mimic the oral environment, in this study. Many studies have stated no significant difference in microleakage whether the samples were subjected to 250, 1000, or 5000 thermocycles. Harper *et al.* suggested 250–500 thermocycles to be used to mimic clinical situation, stressing on the minimum usage of thermocycles to mimic the clinical condition.[13-16] A variety of microleakage testing techniques are available. The simplest and most commonly used method is the dye penetration method. Wu and Cobb developed the silver-staining technique which gives strong optical contrast. Its penetration into specimen can be easily detected when compared with other organic dyes. Silver ion is extremely small (0.059 nm) when compared to a typical bacterium (0.5–0.1 µm). It is more penetrative and hence was used in this study.[12,17,18]

Among the three materials tested in the present study, ORMOCER showed the least microleakage followed by nanocomposite and composite. ORMOCER consists of ceramic polysiloxane which has low shrinkage when compared to organic dimethacrylate monomer matrix seen in composites and nanocomposite. Polymerizable side chains are added to the polysiloxane chains in ORMOCER that reacts during curing, forming a setting matrix. These organic molecules explain the lower volumetric shrinkage and minimal microleakage. Further incorporation of filler particles decreases volumetric shrinkage of 2%–8% when it has no fillers to 1%–3% when fillers are incorporated.[7] When compared with nanocomposites and hybrid composites, ORMOCER has lower water solubility because of the presence of prepolymerized particles and lower monomer elution.[5,19-21] Nanocomposites showed significantly lesser microleakage than composites because of the presence of spherical nanofillers and their broad particle distribution enabling them to obtain high filler loading which decreases the volumetric shrinkage. Nanoparticles differ from composite filler particles in size and their chemistry of addition to the organic matrix, resulting in decreased polymerization shrinkage and less microleakage.[22]

In a systematic review conducted by Monsarrat *et al.*,[23] they did not find any significant difference between first-generation Ormocers and conventional composites. However, they suggested that the recent development of new, dimethacrylate-diluent-free ormocer matrices potentially maybe even more stable. They add that new randomized clinical trials should be developed comparing this new family of pure ormocers with current composites.

Mahmoud *et al*. performed a 3-year evaluation on the Clinical Performance of Ormocer, Nanofilled, and Nanoceramic Resin Composites in Class I and Class II Restorations and concluded that ORMOCER (Admira), nanofilled, nanoceramic, and microhybrid composites, all performed excellent over the 3-year period.[24]

Study limitations and scope for further study

The present study was done under *in vitro* conditions and used natural extracted teeth for restoration, and thermocycling was used as part of test protocol. *In vitro* studies are very important for an early assessment of the dental material. However, only a clinical study takes into account, all the potential variables that vary from patient to patient. Some of the variables include masticatory forces, types of food, oral temperature, and humidity variations and presence of salivary enzymes and bacterial by-products. Many new restorative materials are evolving rapidly, each with better properties and promising results for better performance. Therefore, further studies are required to establish the factual clinical worth of these materials to validate their *in vitro* established results.

Conclusions

In restorative dentistry, choosing the correct restorative material is one of the primary variables that determine its success. Microleakage is one of the factors which affects the performance of the material in the oral cavity. Therefore, based on the results of the present study, it is suggested that the marginal sealing ability of ORMOCER-based composite Admira is superior to Tetric Ceram and Tertic N-Ceram.

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Conflicts of interest

There are no conflicts of interest.

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