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Physico-Mechanical Characteristics of Ormocer and Bulk Fill Composite Resin Restorative Materials: An in-vitro Study

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ABSTRACT

Introduction: Bulk Fill (BF) resins and Ormocers are recently introduced composite restorative materials in order to overcome the disadvantage of polymerisation shrinkage exhibited by most of the conventional resin-based composites.

Aim: To evaluate the physical and mechanical properties of Organically Modified Ceramics (Ormocers) in comparison with BF composite resin restorative material.

Materials and Methods: In this in-vitro study, 20 human extracted premolars were allocated into two groups of 10 each. ORM (Group-1 Admira fusion, n=10) and BF (Group-2 Filtek BF, n=10) composite materials were used to prepare and restore Class-V cavities. The teeth were subjected to thermocycling and immersed in 1% methylene blue dye solution. Along the lateral walls of each sectioned specimen, depth of dye penetration was measured under the stereo microscope. A total of 20 rectangular (25x2x2 mm) and 20 disc (10x2 mm) shaped specimens of the above-mentioned materials were fabricated. Specimens of Flexural Strength (FS) were tested with the universal testing machine and Vickers hardness tester used for Surface Hardness (SH) evaluation. The data was statistically analysed using an unpaired t-test.

Results: Total of 20 extracted premolars were analysed. On inter-group comparison, it was observed that mean dye penetration was lowest for Group-1 (0.6±0.69) compared to Group-2 (2±0.81) and the difference observed was statistically significant (p=0.001). BF exhibited a lower FS of 211.69±43.9 compared to Ormocer 326.19±90.3, the difference is statistically significant (p=0.001). However, BF exhibited a higher SH of 38.3±0.15 compared to Ormocer 33.70±0.86, and the difference is statistically significant (p-value<0.001).

Conclusion: Ormocer exhibited improved marginal integrity and also higher FS compared to BF resin restorative materials. However, BF exhibited higher SH values compared to Ormocer.

Keywords: Flexural properties, Hardness test, Leakage, Organically modified ceramics

INTRODUCTION

Resin-based composite materials are popular aesthetic restorative materials due to their ease of use, minimal loss of tooth structure, and ability to be placed directly. Composite resin materials have become the most widely used posterior tooth restorations and satisfy rising requirement for aesthetics due to a significant improvement in newer generation bonding agents, emerging resin formulations, and recent technologies [1].

In comparison to other restorative materials, dental composites stand out for their handling characteristics, aesthetic appearance, and clinical durability [2]. Inspite of good physical properties, composite resin materials have the following drawbacks: polymerisation shrinkage and stress causing microcracks within the material, bonding agent separation from the cavity lining that could result in formation of a gap. The other diasadvantages includes microleakage, sensitivity, enamel cracks, wear, discolouration, reduced fracture resistance, marginal staining, recurrent carious lesions and deformation [3].

Marginal microleakage is defined as the clinically undetectable passage of bacteria, metabolites, enzymes, toxins, ions, and four other cariogenic factors between the restoration and the cavity lining as described in study by Kidd EA [4]. Clinical consequences of microleakage include secondary caries, pulpal inflammation, discolouration, post-operative sensitivity, and reduced longevity of restoration [5]. The occlusion load and temperature changes in the oral cavity, are leading to the formation of a marginal gap at the contact surface between the tooth and material [6].

Several techniques for reducing polymerisation shrinkage have been predicted. The use of incremental placement of restorative material is one of them [7]. However, this technique has some drawbacks, such as prolonged clinical time, inclusion of air bubbles, and the possibility of clinical errors [8].

To simplify this incremental layering technique and reduce chair time, newer generation of resin composites known as “BF resins” were introduced [8]. Compared to traditional composites, filler-volume percentage is higher in BF composites. The initiator system in BF composites is modified for better physical and mechanical properties to withstand higher masticatory forces [9]. Organically modified ceramic material, a novel resin-based restorative material abbreviated as ORMOCER was recently developed [10]. The goal of this material development was to eliminate polymerisation shrinkage by modifying its composition [11].

A variety of factors must be considered when selecting a suitable resin-based composite for restoration in modern dentistry. This necessitates functional properties such as enhanced restorative longevity as a result of excellent mechanical properties including high strength, SH, and low polymerisation shrinkage [12]. Both BF and Ormocer resin restorative materials exhibit less polymerisation shrinkage [7,11]. Gupta R et al., and Garapati S et al., conducted studies on properties of BF and Ormocer restorative materials individually however, very limited research was available on comparing the physical and mechanical properties of these two materials [1,11]. Therefore, this in-vitro study was intended to evaluate and compare the physico-mechanical properties of Ormocer and BF composite resin restorative materials.

MATERIALS AND METHODS

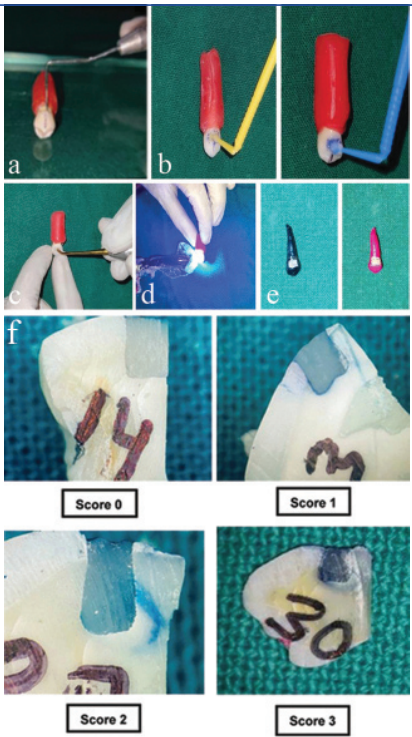
The current in-vitro research was conducted from June 2021 to July 2022, in the Department of Pedodontics, Vishnu Dental College, India. Study design was accepted by Institutional Review Board (IECVDC2021/PGO1/PPD/IVT/33). Two composite restorative materials such as Admira fusion (Voco, Germany), Filtek BF (3M ESPE, St. Paul, Minnesota, USA) were used in the study. A stereomicroscope (Olympus SZX 16), Universal Testing Machine (UTM) (AE-UTM-LC2, Advanced Equipments, India), and Vickers microhardness tester (Daksh Quality Systems Pvt., Ltd., India) were used to assess microleakage, FS and SH, respectively.

Sample size: The sample size was determined using the findings of the pilot study (n=24) using the G power 3.1 software at a level of significance set as 5% and 80% power. A total of 30 samples per group, thus totaling to an effective sample size of 60, for three parameters in two groups. Group-1 Ormocer (Admira fusion, Voco) and Group-2 BF (Filtek, 3 M ESPE).

Procedure

Evaluation of Microleakage [Table/Fig-1]:

Specimens (20 extracted premolars) were stored in 10% formalin solution for 1 week [13]. Class-5 cavities with standardised dimensions were prepared on the buccal surfaces of all teeth (3x2x2 mm) [14]. Following cavity preparation, teeth were etched, and a bonding agent (Admira bond, VOCO [11], 3M™ Single bond universal) was applied as per the manufacturer's instructions for Groups 1 & 2, respectively. Then, half of the samples (n=10) were restored with Ormocer cured using Light Emitting Diode (LED) (Woodpecker Ltd.,) curing light intensity (500 mW/cm²) for 20 seconds, and another half of the samples (n=10) were restored with BF and cured using Elipar™ S10 LED Curing Light (1200 mW/cm²) for 20 seconds according to manufacturers instructions.



[Table/Fig-1]: Photograph showing microleakage evaluation, a) Cavity Preparation; b) Application of etchant and bonding agent; c) Sample packed with material; d) Curing with LED light; e) Coated with nail varnish; f) Samples under stereomicroscope.

Except for one mm around the restoration, the root and crown surfaces were covered with two coats of nail varnish. Samples were subjected to thermocycling with 500 cycles by varying immersion in water at 5°C and 55°C with dwell time of 30 seconds and transfer times of 30 seconds in each bath [14]. Specimens were then suspended in a 2% methylene blue dye solution, and dye penetration depth was measured using the following scoring criteria under a stereomicroscope to determine microleakage [Table/Fig-2] [15].

Evaluation of Flexural Strength (FS): Rectangular (25×2×2 mm) specimens (n=20) were prepared to measure FS. For 10 Samples, Ormocer was packed in the mould and for the other 10 samples, BF composite was packed and specimens were cured, then specimens

Extent of dye penetration	Score
No dye penetration	0
Dye penetration upto half of the cavity depth	1
Dye penetration of more than half of the cavity depth	2
Dye penetration arriving at the cavity floor	3

[Table/Fig-2]: Scores of dye leakage observed for both substrates [15].

were mounted on the holder of the UTM and three point bending test was performed. FS values were then computed in units (MPa).

Evaluation of Surface Hardness (SH): Disc-shaped (10x2 mm) specimens (n=20) were prepared to measure SH. For 10 samples, Ormocer was packed in the mould and for the other 10 samples, BF composite was packed and specimens were cured then specimens were mounted on a Vickers Hardness (VHN) tester and the lens was focused to identify the location to make an indent. The average length of diagonals was measured as the VHN value of the specimen in units kg/mm².

STATISTICAL ANALYSIS

The obtained data was tabulated in Microsoft excel sheet (2019) and subjected to statistical analysis. Since the data was normally distributed, a parametric test (unpaired t-test) was used for intergroup comparison.

RESULTS

Comparison of mean Surface Hardness (SH)

Ormocer (Group-1) exhibited SH values ranging between 32.5 Kg/mm² to 35.2 Kg/mm² whereas BF (Group-2) resin material exhibited SH values ranging between 36.2 Kg/mm² to 39.1 Kg/mm². On intergroup comparison of mean, SH values between the groups, BF showed higher microhardness (38.73±1.15) Kg/mm² compared to the Ormocer (33.7±0.86) Kg/mm² and the difference observed to be significant (p<0.001) [Table/Fig-3].

Groups	Samples (n)	Mean±SD (Kg/mm²)	F value	p-value
Group-1 (ORM)	10	33.7740±0.869	0.669	**<0.001***
Group-2 (BF)	10	38.731±1.15		

[Table/Fig-3]: Intergroup comparison of mean Surface Hardness (SH) values (kg/mm²).
Unpaired t-test *Significant

Comparison of mean Flexural Strength (FS)

Ormocer (Group-1) exhibited FS values ranging between 264 MPa to 520 MPa. Whereas BF (Group-2) resin material exhibited FS values ranging between 135 MPa and 240 MPa. On intergroup comparison of mean FS values between the groups, Ormocer showed higher FS (326.19±90.3) compared to the BF (211.69±43.9) samples, and the significant difference (p=0.001) was noted [Table/Fig-4].

Groups	Samples (n)	Mean±SD (MPa)	F-value	p-value
Group-1 (ORM)	10	326.19±90.3	3.603	**0.001***
Group-2 (BF)	10	211.69±43.9		

[Table/Fig-4]: Intergroup comparison of mean Flexural Strength (FS) values (MPa).
Unpaired t-test *Significant

Comparison of Microleakage

The dye penetration test revealed that five out of ten specimens in Group-1 (ORMOCER) scored 0, four specimens scored 1 and one specimen scored 2 whereas in Group-2 (BF), three out of ten specimens showed Score-1, four had revealed a Score-2, and three exhibited a Score-3. On intergroup comparison, it was observed that mean dye penetration was lowest for Group-1 (0.6±0.69) compared to Group-2 (2±0.81), and significant (p=0.001) difference was seen [Table/Fig-5].

Groups	Samples (n)	Mean±SD (Score)	F value	p-value
Group-1 (ORM)	10	0.6±0.69	0.000	**0.001***
Group-2 (BF)	10	2±0.81		

[Table/Fig-5]: Intergroup comparison of mean values of microleakage.
Unpaired t-test *Significant

DISCUSSION

The present study evaluated physical and mechanical properties of two different composite resin restorative materials. This in-vitro study reported that Ormocer exhibited better marginal integrity and also high FS compared to BF resin restorative materials. BF composites had a higher SH than ormocer.

Physical and mechanical properties are important factors to consider when choosing the best restorative materials because they have a significant impact on clinical durability [16]. Because it measures the resistance of restoration to occlusal forces, FS is a mechanical characteristic associated with fractures [17]. SH determines its longevity, strength, and sustainability, especially in stress-bearing areas [18].

The marginal seal and the absence of leakage are the important factors for the retention of a restoration [19]. Polymerisation shrinkage causes microleakage, which compromises the material's integrity and is responsible for leakage [6]. Numerous aesthetic restorative materials have been tried to withstand various masticatory forces and shrinkage stresses [18]. By varying filler particle size, shape, and concentration, evolutionary research has been conducted in order to reduce shrinkage stresses and to improve properties such as compressive and FS [20].

BF as a composite material has the advantage of being able to be applied in large quantities of 4 mm thickness and cured in a single step with no impact on moisture contamination or polymerisation shrinkage [21]. Ormocer is composed of ceramic polysiloxane, which shrinks less than the organic dimethacrylate monomer matrix found in composites [22]. The current study found that ormocer samples had less microleakage and higher FS when compared to BF resin materials, indicating superior marginal integrity. These findings are in agreement with those of Kalra S et al., stating that ormocer had superior marginal sealing ability when compared to conventional composite and Nanocomposite [22]. Multifunctional silane molecules can bind ormocer's inorganic components to organic polymers. Ormocer was reported to have a 2% volumetric shrinkage, indicating improved marginal integrity [23].

Hardness is an indirect measure of a material's degree of conversion (%) and provides information on the depth of polymerisation [9]. As a result, the current research suggests that BF composites had a higher degree of conversion than ormocer, which could account for their higher SH. This study's findings were consistent with those of Poggio C et al., who conducted a study to evaluate the microhardness of various aesthetic restorative materials after immersion in an acidic drink [24]. This could be due to the chemical composition of cement, specifically the size of the filler particles, the content of the filler particles, and the degree of conversion.

The mechanical properties of composites are widely accepted to be directly related to filler loading. Filtek and admira have 58.4% [25] and 69% [24] filler content by volume, respectively. This slight variation in filler loading explains why ormocer has the highest FS when compared to BF resin materials. In this study, ormocer had the highest FS value of 326.19 MPa when compared to BF composites as it had the highest filler loading of 84% (W/W) [24].

The current study was conducted in-vitro and used extracted teeth for restoration, with thermocycling as a part of the test protocol which completely doesn't simulate the oral conditions. Superior characteristics of Ormocer in-vitro shall be further checked with long-term clinical studies for confirmation under in-vivo conditions.

CONCLUSION(S)

SH of BF composites was greater than that of ormocer. Ormocer, on the other hand, demonstrated better marginal integrity as well as higher FS when compared to BF resin restorative materials. Because there were no residual monomers left after polymerisation, this novel material can be preferred over BF resin restorative material, resulting in lower shrinkage stress.

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