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Three-Dimensional Comparative Evaluation of Wear Rate of Reinforced Glass Ionomer Cement, Bulk-Fill Composite – An in Vitro Analysis

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Abstract

Introduction: The clinical wear of direct restorations, primarily due to occlusal and proximal wear from masticatory forces and micro-movements, presents a significant challenge for clinicians in selecting the most suitable restorative material. The study aims to fill the knowledge gap in the literature by evaluating the wear rate of two direct restorative materials in class I & II cavities using three-dimensional scanning software. The findings of this study will provide valuable insights into the wear behavior of these materials, thereby enhancing the decision-making process for clinicians.

Methodology: 40 extracted sound human molar teeth were selected. Class I and II cavities were prepared and restored with reinforced GIC FX Ultra A2 and Tetric Avo Ceram composite. The teeth were stored until subjected to a chewing simulator for 5000 and 10000 chewing cycles.

Results: The data obtained from the 3D scan was analyzed using SPSS software. There was a statistically significant difference in the wear rate among class I and II cavity preparations, but no significant difference was seen between GIC and composite restorations.

Conclusion: The study concludes that GIC and bulk-fill resin composite restorations showed significant wear after six months and one year. GIC, compared to Composite, showed more significant wear after six months and one year.

Keywords: 3D scan, Bulk fill Composite, Chewing simulator, Clinical wear, Reinforced GIC

Introduction

Wear is a significant issue for dental tissues as they are subjected to abrasion, attrition, and erosion processes, and dental materials need sufficient wear resistance without prejudice for the opposing teeth (1,2). Likewise, Direct restorative materials are subjected to complex wear mechanisms in the human oral environment, including abrasion, attrition, adhesion, corrosive wear, or any combination of these mechanisms. The wear rate for newer or novel materials can first be studied in vitro. Although in-vitro study tools are interesting for screening and can be easily performed, cheaper, and faster than clinical studies, they encounter numerous difficulties in reproducing the complexity of the oral environment (3). Moreover, there is no standardization regarding in vitro test conditions, and the prediction of clinical wear with in vitro studies is still debatable (4). There needs to be more well-validated tools that can also measure the clinical performance of direct restorative materials, especially Glass ionomer cement and composite restoration, as Amalgam is no longer considered under this category for several reasons (5). Hence, this study aims to translate the in-vitro test tool to evaluate the wear performance of glass ionomers and composite restorations in the clinical scenario.

Tooth wear with significant tooth structure loss involving more than 1/3rd of clinical crown exposing dentin is considered severe tooth wear (1,2). Beyond that moment, the progression of tooth wear leads to functional or esthetical problems, so restorative treatment must be prescribed. Minimal invasive treatment options were recommended for restoring tooth wear (3). Direct composite restorations have shown mid- to long-term success results among minimal invasive options. They have shown an annual failure rate of 2.3% after 5.5 years in severe tooth wear patients (4). An acceptable failure rate was obtained using direct composite restorations.

Nevertheless, significant wear facets were detected on the occlusal surfaces. In patients without tooth wear, wear of 'normal' composite resin restorations has been overcome with improved material properties (5). A recent study observed the clinical wear behavior among patients with severe tooth wear, micro-hybrid Composite, and nanocomposite restorations for five years. Apparent wear behavior was seen in both composites (6). The results led to the assumption that wear of composite restorations is enhanced by a high-risk profile such as bruxism and erosive challenges and may become a relevant risk factor in the survival of these restorations.

The cause for wear of restorations is complex. It can be described as a multifactorial process involving a multiple combination of many host factors (7), in which the influence of the patient factors could be a main factor. Besides age, gender, tooth and jaw position, factors such as an increase in the vertical dimension of occlusion (VDO), bite force, and etiological factors (mechanical or chemically related) may be of importance in the wear process (8). Therefore, this clinical study

also aimed to investigate the wear behavior of composite resin restorations based on patient factors such as
Sage, gender, VDO increase, biting force, etiological factors, jaw position, and bearing condition. We hypothesized that the wear of GIC and composite restoration in class I and II cavities on posterior teeth would be similar.

Rationale

The students and clinicians will benefit from knowledge of direct restorative material properties, their selection, and applications from the proposed research results. This study helps to evaluate whether Reinforced GIC is comparable to resin composites in restoring the occlusal cavities under constant force-bearing areas. The study results can enhance the choice and selection of direct restorative materials to restore the class I and II cavities, which are the most common clinical situations requiring restorations and sustainability and are also considered very crucial. The practical implications of this study will equip clinicians with the necessary information to make informed decisions in their practice.

Objectives

The primary objective of this study is to develop a standardized in-vitro test protocol to determine the suitability of Reinforced GIC as a durable permanent direct restorative material in class I and class II cavities compared to bulk-fill resin composite. The protocol was designed to simulate the oral environment as closely as possible, allowing for a more accurate assessment of the materials' wear resistance and clinical performance.

Methodology

Laboratory investigations

A total of 40 extracted human molar teeth were collected and stored in distilled water. These teeth were carefully examined to ensure they were free from any pre-existing wear or damage. Based on the type of cavity configuration, the teeth were divided into two groups: Group I - Class I design and Group II - Class II design. Each group consisted of 20 teeth, providing a sufficient sample size for the study.

The institutional Ethics Committee approved the study, protocol number IEC NDCH/2023/AUG-SEP/P-88. It was conducted in the Conservative Dentistry and Endodontics Department at Narayana Dental College, Nellore, and utilized the testing facilities at Saveetha Dental College & Hospital, Chennai.

The class I cavity preparations: In Group 1, standard class 1 cavities (2x2x2mm3) were prepared in 20 extracted sound human molar teeth. Depending on the type of restorative material, it is subdivided into two groups (n=10), i.e., 1a, which was restored with reinforced GIC, and 1b - using Bulk-fill Resin composite. For GIC restorations, the powder and liquid were mixed on a paper pad according to the manufacturer's instructions and were placed into the cavity. For composite restorations, the cavities were acid-etched with 37% phosphoric acid for 15 s, rinsed for 1 min, and air-dried. Tetric N bond dentin bonding agent was applied, air-dried, and light-cured for 20 s. Teeth were restored with Tetric EvoCeram A2Bulkfill posterior restorative material, light-cured, and finishing and polishing.

Class II cavity preparations: Class II cavities (2x2x1x1mm3) were prepared in 20 extracted sound human molar teeth in Group II. Depending on the restorative material type, it was subdivided into two groups (n=10), i.e., Group 2a – Reinforced GIC and Group 2b - Bulk-fill resin composite. For GIC restorations, the powder and liquid were mixed on a paper pad according to the manufacturer's instructions and placed into the cavity. For composite restoration after cavity preparation, the sectional matrix was applied; the cavity was acid-etched with 37% phosphoric acid for 15 s, rinsed with water for 1 min, and air-dried. Tetric N bond bonding agent was applied, air-dried, and light-cured for 20 s. Teeth were restored with Tetric EvoCeram A2 Bulkfill posterior restorative material and light-cured, finishing, and polishing.

After restorations, the teeth were stored in distilled water for 24 hours. All the samples were subjected to a chewing simulator for 5000 cycles, simulating six months, and 10,000 cycles, simulating 12 months of chewing cycles.

Statistical analysis

The data were collected, tabulated, and analyzed using IBM Corp. Released in 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp. Paired T-test was used to compare each criterion among the two groups at various time intervals ($P < 0.05$).

Results

3D laser scan quantitative analysis of wear on the occlusal surface was quantified regarding the vertical loss in height and the volume loss on the surface of the entire restoration. Table 1 provides the cumulative mean of the vertical loss of the two materials at six months and one year. Between 6 months and one year, both the materials exhibited running-in-wear. The mean wear after one year was 64m (±26) in the GIC FX Ultra group and 75m (±27) in the Tetric EvoCeram group. Statistically significant differences (p<0.05, Paired T-test) were observed between both groups. In addition, the mean vertical loss magnitude of class 1 restorations compared to class 2 restorations was not significantly different (p = 0.24; Mann–Whitney U test). The volumetric wear of the GIC group was 0.36 (±0.2) mm3, and the Composite group was 0.27 (±0.1) mm3. The volume loss of GIC group remained significantly higher (p = 0.0008; Independent T-test) 0.18 (±0.1) mm3 in Tetric EvoCeram group and 0.138 (±0.1) mm3 in Filtek Supreme group (p = 0.0017)

Discussion

Wear is a significant issue for dental tissues subjected to abrasion, attrition, and erosion processes [9] and for dental materials that must be sufficiently wear-resistant without being prejudicial for the opposing teeth. Wear is a common and critical issue for dental materials and dental tissues. They are continuously subjected to occlusal masticatory forces, which are the process of abrasion, erosion, and attrition; hence, wear is a significant finding to be seen clinically. Though it is a vital aspect to resolve, there was no standard method to measure the wear. Many techniques and approaches, like in-vitro studies, clinical scanning methods, etc., were used to measure and calculate wear. (10)

Many studies have included tooth wear assessment in the literature, which can be measured using qualitative and quantitative methods. Qualitative methods are subjective and lack precision, accuracy, and reproducibility. In vitro studies can be easily performed, are economical, and require less time than clinical studies, but they encounter numerous complications in mimicking the complexity of the oral environment. The assessment of clinical wear by in vitro studies is still debatable as there is no proper or known standardization for in vitro test conditions. Those methods can be considered semi-quantitative (11); they do not allow for an accurate wear quantification and tend to underestimate the amount of substance loss.

In the literature, various methods were stated to be used to evaluate the clinical wear of tooth and dental material. Many authors measured wear qualitatively by using visual assessments along with various indexes. (12) Some authors measured wear using semi-quantitative methods like indirect methods using casts and comparing them with standard models. However, these methods cannot quantify the accurate wear, which can lead to missing the actual amount of substance loss.

The quality of the scanning procedure is influenced by the following parameters: the width of the laser spot/stylus size, the resolution in the three axes x/y/z, the scanning step, the angulation of the sample, the depth range, and the optical properties of the material. The obtained cloud of points is subsequently treated with mathematical models to extrapolate the whole surface. At each evaluation time, the digital reconstructions obtained are superimposed with metrology software called matching software. (13)

The use of Intraoral scanners is rapidly progressing in various fields of dentistry. Already, they were regularly used in making diagnostic cast impressions, transferring the records, and recording the measurements for a prosthesis. Recently, they have been introduced to measure the wear of dental tissues and restorative materials. Some studies suggested that 3D Software and the scanning method of measuring the wear are accurate in clinical scenarios. This might be a complicated method to assess occlusal tooth/restorative material wear through serial 3D surface model superimpositions. There needs to be a study in the literature that has addressed this issue. (14)

After statistically analyzing the data, it was observed that the wear resistance among the GIC exhibited more variability than that of bulk-fill composites tetric Evo Ceram, leading to the rejection of the null hypothesis. Nanotechnology was used to manufacture Tetric Avo Ceram, which allows for better polishing and lower shrinkage. The total content of inorganic fillers for the bleach shades is 60-61% by volume (79-80% by weight), and for all other shades, 53-55% by volume (75-76% by weight).

In this study, a chewing simulator was used to effectively simulate the dynamics of chewing movements. A masticatory force of 49 N was applied at a frequency of approximately 1–1.6 Hz during the simulation, consistent with other researchers, a value reported by Gibbs *et al.* (15) as the average masticatory force observed under normal chewing function. The specimen surfaces were cleared from debris, wet conditions were maintained throughout the test, and continuous thermal cycling was conducted between temperatures of 5°C and 55°C, contributing to additional specimen aging. The study included restorations in natural human teeth to enhance the clinical relevance and deepen the understanding of the performance of the tested GIC and composite resins. Further research is recommended in clinical trials to assess the clinical wear's correlation with the laboratory results.

Conclusion

Assessing the clinical wear of permanent restorations is essential for the clinician to know, as the durability of the restorations remains a primary concern for the patients. There are very few studies or research on the clinical wear of restorative materials; hence, there is a need to identify the best method for evaluating clinical wear. The study becomes the first to assess the three-dimensional wear of restorative materials on extracted teeth. The wear must correlate clinically in patients to confirm the wear assessment; hence, a clinical study will be continued in patients restoring with reinforced GIC and Composite in class I and II cavities.

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Legend Tables and Figures

Table 1: Intergroup comparison among the groups

Groups	Intervals	Type of Material	Mean	Std. Deviation	T value	p-value
Group 1	6 months	GIC	-.0063	.00452	19.89	0.000*
		Composite	-.1086	.01206		
	12 months	GIC	-.0125	.00206	6.268	0.008*
		Composite	-.1126	.03202		
Group 2	6 months	GIC	-.0026	.00717	13.302	0.001*
		Composite	-.0898	.01027		
	12 months	GIC	-.0099	.00299	6.111	0.009*
		Composite	-.1178	.03266		

Paired t-test p<0.05* significant

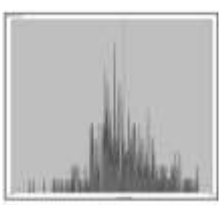
Table: 2 Intragroup comparisons among the groups

Groups		Intervals	Mean	Std. Deviation	T value	value
Class I restorations	6 months	Group 1a	-.0063	.00452	-.850	0.428(NS)
		Group 1b	-.0026	.00717		
	12 months	Group 1a	-.1086	.01206	-2.367	0.06(NS)
		Group 1b	-.0898	.01027		
Class II restorations	6 months	Group 2a	-.0125	.00206	-1.417	0.206(NS)
		Group 2b	-.0099	.00299		
	12 months	Group 2a	-.1126	.03202	0.227	0.828(NS)
		Group 2b	-.1178	.03266		

Independent t-test p<0.05* significant

Result Data - 1: 3D compare of Composite **3D compare of GIC**

Six months

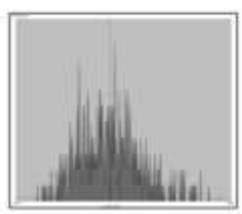


Min.	-1.747
Max.	2.8863
Avg.	0.4059
RMS	1.0711
Std. Dev.	0.9913
Var.	0.9826
+Avg.	0.8581
-Avg.	-0.9633

One Year

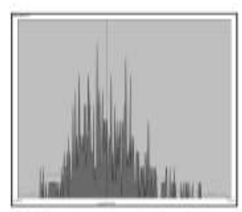
Min.	-0.0426
Max.	0.0407
Avg.	-0.0084
RMS	0.0177
Std. Dev.	0.0166
Var.	0.0003
+Avg.	0.011
-Avg.	-0.0168

6 months



Min.	-0.0537
Max.	0.0536
Avg.	-0.0084
RMS	0.0214
Std. Dev.	0.0197
Var.	0.0004
+Avg.	0.0143
-Avg.	-0.019

One Year



Min.	-0.0562
Max.	0.0513
Avg.	-0.0117
RMS	0.0231
Std. Dev.	0.02
Var.	0.0004
+Avg.	0.0132
-Avg.	-0.0214

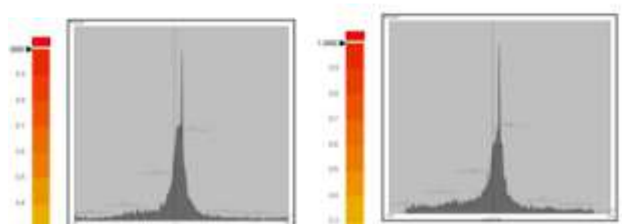
Figure 1: Reinforced GIC (FX Ultra A2 – Shofu)

Figure 2: Bulkfill Composite (Tetric Avo Ceram A2)

Figure 3: Extracted teeth

Figure 4: Class I and II Cavity Preparations done on Extracted teeth

Figure 5: Chewing Simulator



Min.	-1.3138
Max.	1.3178
Avg.	-0.0847
RMS	0.4897
Std. Dev.	0.4888
Var.	0.1686
+Avg.	0.2775
-Avg.	-0.2451
In Tol.(%)	48.4904
Out Tol.(%)	51.5096
Over Tol.(%)	16.1019
Under Tol.(%)	35.4077

Min.	-1.4215
Max.	1.4232
Avg.	-0.1206
RMS	0.5349
Std. Dev.	0.5212
Var.	0.2716
+Avg.	0.3465
-Avg.	-0.3698
In Tol.(%)	37.3968
Out Tol.(%)	62.6032
Over Tol.(%)	20.18
Under Tol.(%)	42.4231