Evaluation of Two-Body Wear of Different Resin Composite Restorations and the Effect of Layer Thickness

Farklı Kompozit Rezin Restorasyonlarda Direkt Temas Aşınması ve Tabakalama Kalınlığının Aşınmaya Olan Etkisinin Değerlendirilmesi

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ABSTRACT

INTRODUCTION: This in-vitro study aims to comparatively assess the two-body wear of methacrylate/ormocer-based composites, methacrylate/ormocer-based bulk-fill composites(BFC), and nanohybrid CAD/CAM block restorations exposed to thermo-mechanical chewing simulation.

METHODS: Mesial–occlusal–distal cavities were prepared in 100 noncarious extracted molars, and restored with Admira Fusion/A+Admira Fusion Flow/AF; Admira Fusion x-tra/AFX+Admira Fusion x-base/AFB; x-tra fil/X+x-tra base/XB; Tetric N-Ceram Bulk Fill/TB+Tetric N-Flow Bulk Fill/TFB; Tetric N-Ceram/T+Tetric N-Flow/TF; GrandioSo/G+GrandioSo Flow/GF; and Grandio Block/GB as per the manufacturer's instructions. The composites in bulk-fill groups were applied in 2-and 4-mm thick layers to investigate the effects of material thickness on wear. Restorations were exposed to 240,000 thermomechanical cycles in chewing simulator. Surfaces were scanned using laser scanner before and after loading. Volume loss was calculated using Geomagic Control program. The Kruskal–Wallis and Dunn tests were used for statistical analysis of the data.

RESULTS: No significant difference was found between groups of the same materials layered with different thicknesses. A statistically significant difference in median wear values was observed between restorative material groups (p=0.006), and the wear values of A+AF(0.351) were higher than TB (4 mm)+TFB (2 mm)(0.045).

CONCLUSION: CAD/CAM block and direct resin composite restorations did not differ in wear resistance. Also, all tested direct materials exhibited similar two-body wear resistance, except for ormocer-based composite, which had higher wear values.

Keywords: *CAD/CAM, Chewing simulator, Nanohybrid resin composite, Wear*

ÖZ

GİRİŞ ve AMAÇ: Bu in vitro çalışmada, çiğneme simulatörü ile termo-mekanik döngüye maruz bırakılan metakrilat/ormoser esaslı kompozitlerin, metakrilat/ormoser esaslı bulk-fill kompozit rezinlerin ve nanohibrit CAD/CAM blok restorasyonların direkt temas aşınmasını karşılaştırmalı olarak değerlendirmek amaçlanmaktadır.

YÖNTEM ve GEREÇLER: Çürüksüz, çekilmiş 100 adet azı dişinde hazırlanan mesial-oklüzal-distal kaviteler Admira Fusion/A+Admira Fusion Flow/AF; Admira Fusion x-tra/AFX+Admira Fusion x-base/AFB; x-tra fil/X+x-tra base/XB; Tetric N-Ceram Bulk Fill/TB+Tetric N-Flow Bulk Fill/TFB; Tetric N-Ceram/T+Tetric N-Flow/TF; GrandioSo/G+GrandioSo Flow/GF; ve Grandio Block/GB ile üreticinin talimatlarına göre restore edildi. Bulk-fill gruplarındaki kompozitler, materyal kalınlığının aşınmaya olan etkisini araştırmak amacıyla 2 ve 4 mm kalınlığında tabakalar halinde uygulandı. Restorasyonlar çiğneme simülatöründe 240.000 termomekanik döngüye maruz bırakıldı. Yükleme öncesinde ve sonrasında yüzeyler lazer tarayıcı kullanılarak tarandı. Hacim kaybı Geomagic Control programı kullanılarak hesaplandı. Verileri karşılaştırmak ve analiz etmek için Kruskal-Wallis ve Dunn testleri kullanıldı.

BULGULAR: Aynı materyalin farklı kalınlıklarda tabakalandığı gruplar arasında anlamlı bir fark bulunmadı. Farklı restoratif materyal grupları arasında medyan aşınma değerlerinde istatistiksel olarak anlamlı bir fark gözlendi (p=0,006), ve A+AF grubunun (0,351) aşınma değerleri TB (4 mm)+TFB (2 mm) grubuna (0,045) göre daha yüksekti.

SONUÇ: Nanohibrit CAD/CAM blok restorasyonlar ve direkt rezin kompozit restorasyonlar aşınma direnci açısından farklılık göstermedi. Ayrıca daha yüksek aşınma değerlerine sahip olan ormoser esaslı kompozit restorasyonlar dışında, test edilen tüm direkt kompozit restorasyonlar benzer direkt temas aşınma direnci sergiledi.

Anahtar Kelimeler: *Aşınma, CAD/CAM, Çiğneme simülatörü, Nanohibrit rezin kompozit*

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INTRODUCTION

Composite restorations have many complementary mechanical factors such as shrinkage, wear resistance, water absorption, and fracture resistance that can impact clinical performance.[1] In some clinical situations, wear may adversely affect the function and esthetics of restorations and also cause systemic consequences through ingestion or inhalation of the abraded materials.[2] Therefore, the wear resistance of restorative materials plays a crucial role in the maintenance of the restorations as well as the antagonist teeth in the opposing arch, highlighting the importance of investigating both in relation to one another. It aims to identify restorative materials resembling enamel tissues in terms of their physical and biological properties to maintain a balance in wear resistance between the two.[3]

Abrasion and attrition are the main mechanisms of dental material wear.[4] Abrasive wear is caused by the movement of hard particles or protrusions against firm surfaces and can be classified into two-body and three-body wear. Attrition is a type of two-body wear in which the teeth or restorations are in occlusal contact, while three-body wear can be defined as abrasive wear caused by the presence of food particles between the teeth or restorations and their antagonists during mastication. These mechanisms and their combinations often lead to material loss and changes in morphology.[5]

Variable conditions in the oral environment and differences in mechanisms make it difficult to evaluate wear using a single test method, resulting in the development of a range of different wear resistance tests. ISO/TS 14569-2, which defines wear caused by occlusal contact between the teeth and their antagonists, aims to define wear tests and parameters.[6] Several laboratory studies have used chewing simulators to predict the clinical wear resistance of restorative materials.[7, 8] The results showed that wear produced by 240,000–250,000 thermo-mechanical cycles in a chewing simulator was equivalent to that produced by a year of clinical performance.[9] Profilometers,[10] laser scanners,[11] and other similar methods have also been used to measure wear with limited material loss.

The amount and pattern of wear may vary depending on the content and mechanical properties of the restorative material and the antagonist as well as the severity and duration of forces it is exposed to.[9, 12, 13] Parafunctional occlusal habits such as bruxism, which generate increased forces on the restoration and teeth, are frequently encountered and are reported to cause faster wear.[3, 14] The development of resin composites and improvements in the inorganic and organic matrix content have aimed to increase wear resistance.[15] Studies have suggested that this may be affected by silicon dioxide which forms the inorganic and organic structures of ormocer composites, or by the high degrees of polymerization conversion of bulk-fill composites (BFC).[16]

Moreover, while some studies suggest that the volume percentage [12] and the size of filler particles may affect wear, others have demonstrated contradictory results on the effect of particle size and volume percentage on wear.[10, 17, 18] The current study aimed to compare the wear resistance rates of several resin composite restorations differing in techniques, fillers, and matrix types under *in vitro* abrasive conditions created by exposure to thermo-mechanical cycles. For this purpose, ormocer-based resin composites, ormocer-based BFC, methacrylate-based resin composites, methacrylate-based BFC composites, and nanoceramic hybrid CAD/CAM block were tested using a dual-axis chewing simulator.

The null hypotheses tested were as follows:

1) Direct resin restorative materials and indirect resin restorative material, the nanoceramic hybrid CAD/CAM block, would exhibit similar two-body wear resistance.

2) Different types of matrix structure (ormocer vs. methacrylate) would not affect the wear values of the restorations.

3) Groups restored with BFC of different thicknesses (2 mm–4 mm) would exhibit similar two-body wear resistance.

MATERIALS AND METHODS

This study was approved by the ethics committee of Marmara University, Faculty of Dentistry in Istanbul, Türkiye (Protocol number 2020/58).

Standardized mesial–occlusal–distal (MOD) cavities (an occlusal isthmus of 3 mm in width/2 mm in depth and proximal boxes of 4 mm in depth/2 mm in width) were prepared in noncarious, nonrestored mandibular molar teeth extracted within the last 6 months and stored in thymol for 24 hours before commencement of the procedure. MOD cavities were randomly divided into groups and restored using ormocer-based composites (Admira Fusion/A + Admira Fusion Flow/AF); ormocer-based bulk-fill composites (Admira Fusion x-tra/AFX + Admira Fusion x-base/AFB); methacrylate-based bulk-fill composites (X-tra fil/X + X-tra base/XB and Tetric N-Ceram Bulk Fill/TB + Tetric N-Flow Bulk Fill/TFB); methacrylate-based composites (Tetric N-Ceram/T + Tetric N-Flow/TF and GrandioSo/G + GrandioSo Flow/GF); and nanohybrid CAD/CAM block (Grandio Blocs/GB), as per the manufacturer's instructions.

Methacrylate and ormocer-based BFC (AFX + AFB, X + XB, and TB + TFB) were applied at different thicknesses in two experimental groups to evaluate their effects on wear. Using the restorative materials shown in Table 1, a total of 10 experimental groups were obtained (n = 10 per material; Table 2).

Table 1. Materials and equipment used in the restoration of MOD cavities

	Restorative material	Matrix and filler contents	Flowable restorative material (As a liner)	Matrix and filler contents
Direct restorative materials Bulk-fill resin composites	***Admira Fusion x-tra*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, silicon dioxide, glass ceramics; Filler (% w/w): 84	***Admira Fusion x-base*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, silicon dioxide, glass ceramics; Filler (% w/w):72
	X-tra fil VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, UDMA, barium aluminium silicate, fumed silica, pigments; Filler (% w/w): 86	***X-tra base*** VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-EMA, aluminium, barium silicate; Filler (% w/w): 75
	Tetric N-Ceram Bulk Fill Ivoclar Vivadent, Schaan, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, barium glass, prepolymer, ytterbium trifluoride, mixed oxide; Filler (% w/w): 75-77	***Tetric N-Flow Bulk Fill*** Ivoclar Vivadent, Schaan, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, TEGDMA, barium glass, ytterbium trifluoride, copolymers; Filler (% w/w):68.2
Direct restorative materials Resin composites	***Admira Fusion*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix, glass-ceramic, silicon oxide; Filler (% w/w): 84	***Admira Fusion Flow*** VOCO, Cuxhaven, Germany (Ormocer-based)	Ormocer matrix; Filler (% w/w):74
	GrandioSo VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, Bis-EMA, glass-ceramic and silica nanoparticles; Filler (% w/w): 89	***GrandioSo Flow*** VOCO, Cuxhaven, Germany (Methacrylate-based)	Bis-GMA, TEGDMA, HEDMA, glass ceramic, silicon dioxide; Filler (% w/w):81
	Tetric N-Ceram Ivoclar Vivadent, Schann, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, barium glass, ytterbium trifluoride, mixed oxide; Filler (% w/w): 80	***Tetric N-Flow*** Ivoclar Vivadent, Schann, Liechtenstein (Methacrylate-based)	Bis-GMA, UDMA, TEGDMA, Bis-EMA, barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide; Filler (% w/w): 63.8
	Brand name and manufacturer		**Matrix and filler contents**	
Indirect restorative materials	***Grandio Blocs*** VOCO, Cuxhaven, Germany (Nanohybrid CAD/CAM block)		86% w/w inorganic fillers in a polymer matrix-14% UDMA+DMA	
Adhesive and luting system	***Futurabond U Universal (***VOCO, Cuxhaven, Germany)		HEMA, Bis-GMA, HEDMA, acidic adhesive monomer, UDMA, catalyst, silica nanoparticle, ethanol	
	Bifix QM Dual-cure (VOCO, Cuxhaven, Germany)		Bis-GMA, HEMA, benzoyl peroxide, high fluoride amin	
	Tetric N-Bond Universal (Ivoclar Vivadent, Schann, Liechtenstein)		Phosphoric acid acrylate, HEMA, Bis-GMA, UDMA, ethanol	
	Futura Bond DC Universal (VOCO, Cuxhaven, Germany)		Bis-GMA, HEMA, ethanol, acidic adhesive monomer	
	Ceramic bond (VOCO, Cuxhaven, Germany)		Organic acid, 3-methacryloxypropyltrimethoxysilane and acetone	
Light device: *Valo Cordless (*Ultradent, USA) Standard mode: 1000 mW / cm^2				

*Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate, Bis-GMA: Bisphenol A dimethacrylate, DMA: Dimethylacetamide, HEDMA: hexamethylene dimethacrylate, HEMA: 2-hydroxyethyl methacrylate, TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate

Table 2. Restoration stages of groups by materials used

Groups					
Group 1 AF as a liner in 1 mm layer, and A in 2 mm layers.	**Group 2** AFB as a liner in 2 mm layer, and AFX in 4 mm layer.	**Group 3** AFB as a liner in 4 mm layer, and AFX in 2 mm layer.	**Group 4** XB as a liner in 2 mm layer, and X in 4 mm layer.	**Group 5** XB as a liner in 4 mm layer, and X in 2 mm layer.	**Group 6** GF as a liner in 1 mm layer, and G in 2 mm layers.
In groups 1-6: **Etching and adhesive protocol:** The enamel surface was etched with Vococid (35%-H_3PO_4; VOCO, Cuxhaven, Germany) in selective mode. Futurabond U was applied to enamel and dentin surface (10 s). **Polishing protocol:** Finishing and polishing of the restoration was completed using Dimanto (VOCO, Cuxhaven, Germany).					

Groups		
Group 7 TF as a liner in 1mm layer, and T in 2 mm layers.	**Group 8** TFB as a liner in 2 mm layer, and TB in 4 mm layer.	**Group 9** TFB as a liner in 4 mm layer, and TB in 2 mm layer.
In groups 7-9: **Etching and adhesive protocol:** The enamel surface was etched with N-Etch (37%-H_3PO_4; Ivoclar Vivadent, Schann, Liechtenstein) in selective mode. Tetric N-Bond (Ivoclar Vivadent, Schann, Liechtenstein) was applied to the enamel and dentin surface (10 s). **Polishing protocol:** Finishing and polishing of the restoration was completed using OptraPol (Ivoclar Vivadent, Schann, Liechtenstein).		

Group 10 Grandio Blocs
In group 10: **Etching and adhesive protocol:** The enamel surface was etched with Vococid (35%-H_3PO_4; VOCO, Cuxhaven, Germany) in selective mode. Futurabond DC was applied to the enamel, dentin, and restoration surface (10 s), followed by application of Ceramic Bond to the restoration surface (60 s). Nanoceramic hybrid (GB) restorations were luted with Bifix QM Dual-cure. **Polishing protocol:** Finishing and polishing of the restoration was completed using Dimanto (VOCO, Cuxhaven, Germany).

*H_3PO_4: Phosphoric acid

The teeth were embedded in the molds of the chewing simulator using self-cure acrylic (Imicryl, Konya, Türkiye), and samples of each restorative material were thermodynamically loaded in a dual-axis chewing simulator (CS-4.8, SD Mechatronic, Feldkirchen, Westerham, Germany) with steel balls as the antagonist (1.7 Hz, 50 N load; 240,000 mechanical cycles; and thermal cycling 5°C–55°C at 60 sec dwell time) (Figure 1). Two-way movements along the vertical and horizontal axes were carried out using a force of 50 N, and steel balls with a diameter of 6 mm were used as the antagonists.

Parameters of chewing simulator	Test conditions
Number of thermo-mechanical cycles	240 000 cycles
Antagonist material/shape/size	Steel/ball/6mm diameter
Applied force	50 N
Dwell time	60 s
Cycle frequency	1.7 Hz
Cold/hot bath temperature	5◦C/55◦C
Z-axis (Vertical);	
Stroke up/down	3.0 mm/3.0 mm
Speed up	55.0 mm/s
Speed down	30.0 mm/s
X-axis (Horizontal)	
Stroke horizontal	0.3 mm
Speed horizontal	30.0 mm/s

Figure 1. Chewing simulator parameters

High-resolution (10 µm) topography scanning of the wear craters was performed using a laser scanner (LAS-20, SD Mechatronic, Münich, Germany), and surface topography analyses were carried out before and after loading to calculate the volume loss of samples. The starting and ending points of the surfaces of the samples to be scanned were marked. The measurement step of the scanning was adjusted to 0.02 mm and 3D surface scanning operations were carried out. The data transferred to the Geomagic Control (3D Systems Inc., Rock Hill, USA) program was superimposed to detect areas where wear occurred (Figures 2 and 3).

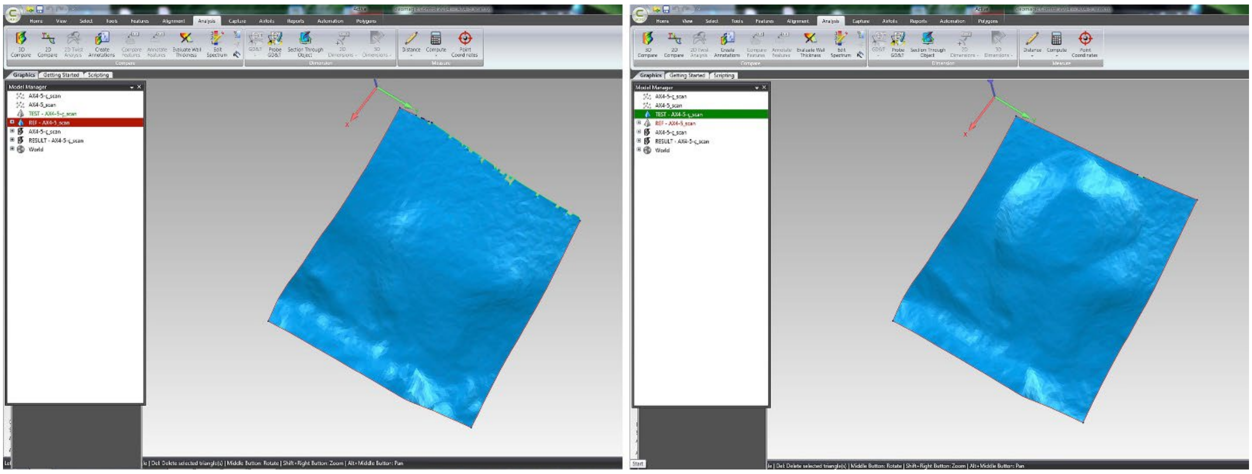

Figure 2. Obtaining a virtual model from three-dimensional surface analysis before (a) and after (b) loading

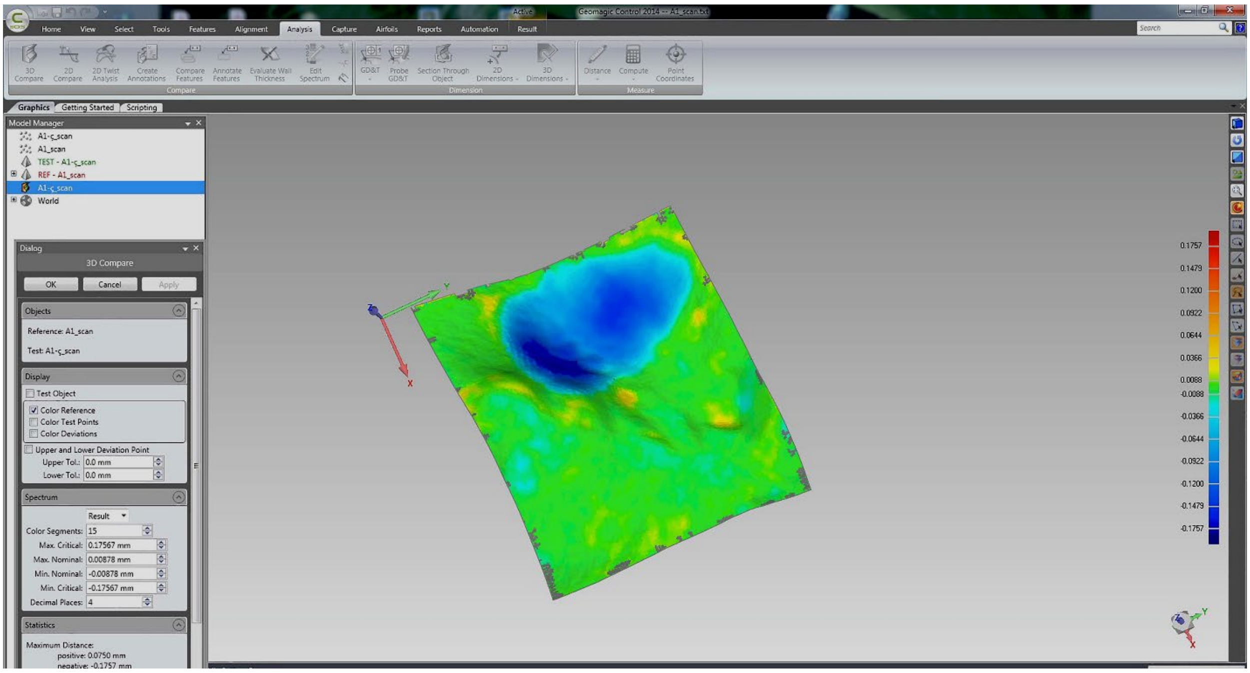

Figure 3. Superimposed 3D images with the three-point alignment method

The superimposed images were kept at the same time and cut to equal sizes. After arrangement, the volumetric distances of the initial and final states of each sample to a certain plane were calculated separately and the amount of volumetric wear that occurred was determined (Figure 4).

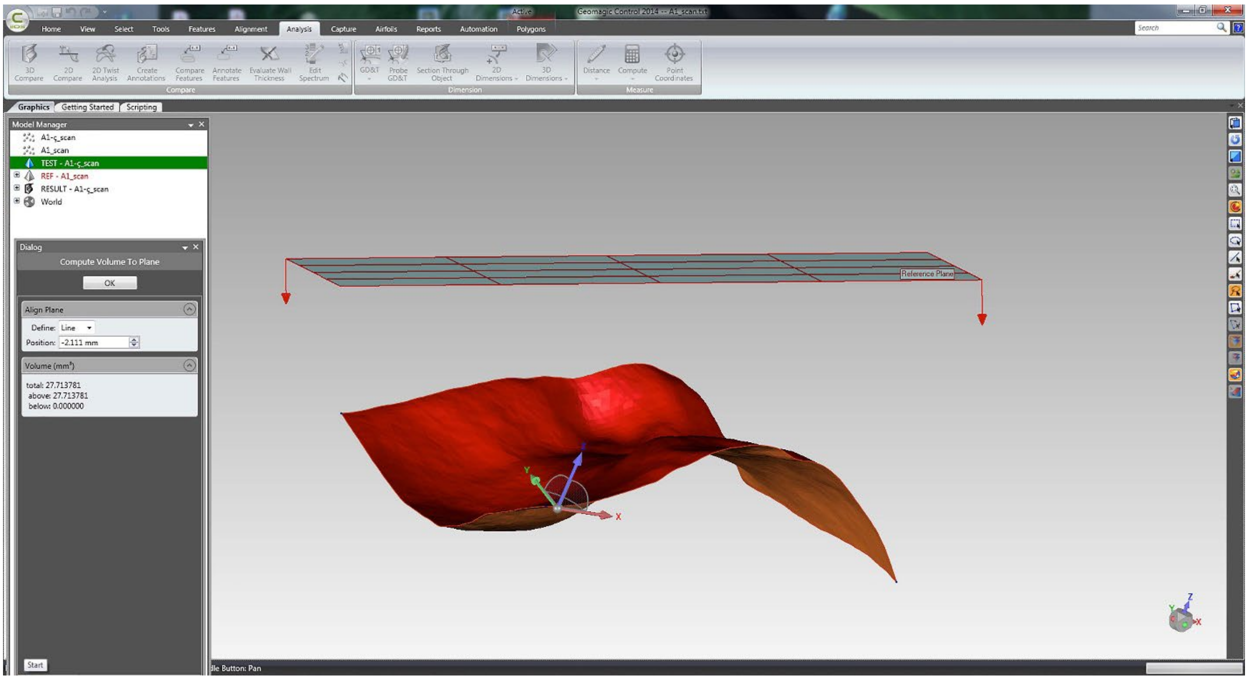

Figure 4. Calculation of the volumetric distance of the 3D images (before and after loading) to the plane

Statistical analysis

Data were analyzed using the SPSS V23 (IBM SPSS, Armonk, USA), and conformity to the normal distribution was evaluated using the Shapiro–Wilk test. The Kruskal–Wallis test was used to carry out group-wise comparisons of data that were not normally distributed, while multiple comparisons were analyzed using the Dunn test. The analysis results were presented as mean ± standard deviation and median (α = 0.05).

RESULTS

Descriptive statistics for volume loss after chewing simulation in each group are shown in Table 3.

Table 3. Comparison of wear values (mm^3) according to groups

Groups	Mean ± s. deviation	Median (min. - max.)	Test statistic	p
Group 1 (Admira Fusion+ Admira Fusion Flow)	0.460 ± 0.303	0.351(0.187 - 1.002)^{a}	X^2=23.321	**0.006**
Group 2 (Admira Fusion x-tra 4 mm+ Admira Fusion x-base 2 mm)	0.316 ± 0.390	0.107 (0.001 - 1.191)^{ab}		
Group 3 (Admira Fusion x-tra 2 mm+ Admira Fusion x-base 4 mm)	0.270 ± 0.338	0.118 (0.030 - 1.135)^{ab}		
Group 4 (x-tra fil 4 mm+ x-tra base 2 mm)	0.077 ± 0.074	0.049 (0.022 – 0.161)^{ab}		
Group 5 (x-tra fil 2 mm+ x-tra base 4 mm)	0.119 ± 0.085	0.109 (0.016 – 0.314)^{ab}		
Group 6 (GrandioSo+ GrandioSo Flow)	0.158 ± 0.203	0.092 (0.011 – 0.503)^{ab}		
Group 7 (Tetric N-Ceram+ Tetric N-Flow)	0.054 ± 0.069	0.014 (0.014 – 0.133)^{ab}		
Group 8 (Tetric N-Ceram Bulk Fill 4 mm+ Tetric N-Flow Bulk Fill 2 mm)	0.059 ± 0.049	0.045 (0.007 – 0.138)^{b}		
Group 9 (Tetric N-Ceram Bulk Fill 2 mm+ Tetric N-Flow Bulk Fill 4 mm)	0.068 ± 0.043	0.060 (0.030 – 0.114)^{ab}		
Group 10 (Grandio Blocs)	0.115 ± 0.083	0.099 (0.035 – 0.228)^{ab}		

* χ^2: Kruskal Wallis test, a-b: No difference between groups with the same letter

Group A+AF showed the maximum mean wear value (0.460 ± 0.303 mm^3), followed by groups AFX 4 mm+AFB 2mm (0,316 ± 0,390 mm^3), AFX 2 mm+AFB 4 mm (0.270 ± 0.338 mm^3), G+GF (0.158 ± 0.203 mm^3), X+XB 4 mm (0.119 ± 0.085 mm^3), GB (0.115 ± 0.083 mm^3), X 4 mm+XB 2 mm (0.077 ± 0.074 mm^3), TB 2 mm+TFB 4 mm (0.068 ± 0.043 mm^3), TB 4 mm+TFB 2 mm (0.059 ± 0.049 mm^3) and T+TF (0.054 ± 0.069 mm^3), respectively. A statistically significant difference in median wear change was observed between the groups ($p = 0.006$), and this could largely be attributed to the differences between groups A + AF and TB (4 mm) + TFB (2 mm).

DISCUSSION

Numerous *in vivo* and *in vitro* studies have compared the wear resistance of dental materials,[1,19] by using chewing simulators; simple configuration tests such as pin-on-plate, ball-on-plate, or pin-on-disc; and wear simulation devices to mimic wear conditions.[9,20,21] Steatite, stainless steel, aluminum, enamel, and zirconia have been used as antagonists in the studies.[11,18,22] The oral environment and chewing conditions are difficult to mimic in a standardized manner due to several parameters and, the current study used a chewing simulator to replicate them. Stainless steel balls were preferred in this study due to the challenges in standardizing the morphological and physical properties of enamel as an antagonist.[22] Based on previous evidence that suggests teeth and restorative materials are exposed to forces ranging between 20 and 120 N in the oral environment, a force of 50 N was applied to the restorations in the current study.[7]

Although composite restorative materials were developed as a solution to the limitations of amalgam (e.g., mercury toxicity and poor esthetic properties), their comparatively lower elastic modulus suggests that they may be more susceptible to deformation and abrasion.[15] Various advancements and modifications in resin composites have resulted in improved mechanical properties, although wear and fracture of the tooth restorations as a result of parafunctional activity still play a crucial role in the failure of restorations.[15, 23] CAD/CAM blocks have been predicted to exhibit higher wear resistance based on previous evidence that suggests the beneficial effects of polymerization under high pressure and temperature during the production process.[24] Grandio Blocs were preferred in the current study due to limited evidence on their wear resistance. Comparison of two-body wear resistance between nanohybrid CAD/CAM blocks and direct composites with different matrix structures showed no significant differences. Therefore, the hypothesis that direct resin restorative materials and indirect resin restorative material, the nanoceramic hybrid CAD/CAM block, would exhibit similar two-body wear resistance was accepted. A similar outcome was also observed in the study of Mörmann *et al.*; it was reported that there were no significant differences in two-body wear resistance between CAD/CAM block nanocomposites and direct light-cured composites, although examination under X1.00 K revealed singular thin microcracks on the surfaces of the CAD/CAM blocks and circular microcracks, micropores, and defects on the surfaces of the direct composites.[25]

Composites with different matrix structures have different functional groups, molecular weights, and reactivity ratios that affect the degree of conversion and cross-linking density. The wear that occurs initially in the organic matrix due to the biting force and lateral movement mechanism results in volume loss and surface roughness in inorganic monomer structures. The particles broken off from the inorganic monomer structure are compressed by the grinding process, preventing deformation of the organic matrix structure.[26] This process reveals the determining role of monomer structure and cross-linking density on the mechanical properties of the composite, such as two-body wear behavior.[27] The organic matrix exhibiting higher cross-linking density has a rigid and more stable polymer chain network. This network results in a lower breakdown or degradation risk under thermal stress. On the other hand, it should be considered that the correlation between cross-linking density and degradation temperature is multifactorial, such as the matrix chemical composition and the type or amount of fillers in the resin composite. UDMA has a higher degree of cross-linking compared to Bis-GMA, which may result in improved mechanical properties and wear resistance. It is thought that the properties of TEGDMA, which are vulnerable to water absorption and degradation, may negatively affect its wear resistance in the long term.[27, 28] In order to improve the esthetic and mechanical properties of composite materials, their matrix structure and filling content have been modified, and innovative dental restorative materials, such as Bis-GMA free ormocers, have been introduced. It has been suggested that the large matrix monomer content of ormocer-based composites decreases polymerization shrinkage and wear,[29] although studies examining the effects of brushing on Admira Fusion X-tra reported increased surface roughness and wear when compared to other composites.[30-32] Augusto *et al*. evaluated the effect of toothpaste on composites with different organic matrixes and found that ormocer-based composites exhibited higher wear values compared to methacrylate-based composites.[33] In contrast, Hahnel *et al*. reported that an ormocer-based composite, Admira, exhibited similar wear resistance when compared to micro and nano-filled materials.[11] In the current study, a statistically significant difference in two-body wear resistance was observed between groups A + AF and TB (4 mm) + TFB (2 mm), and no difference was observed between any of the other groups. Therefore, the hypothesis that different types of matrix structure (ormocer vs. methacrylate) would not affect the wear values of the restorations was partially rejected. Despite its higher filler content, Admira Fusion (84% w/w; silicon oxide, glass-ceramic filler size <1 µm; mean 0.7 µm, range 0.04–1.2 µm) exhibits higher wear values compared to Tetric N-Ceram Bulk Fill (75%–77% w/w; inorganic filler particle size 0.04–3 µm, mean 0.6 µm), which can be attributed to its organic matrix structure. The organic matrix of Tetric N-Ceram Bulk Fill composites, consisting of UDMA and Bis-GMA, may explain their relatively high wear resistance.

Wear resistance plays an important role in the clinical performance of restorations, highlighting the importance of material selection, and it is affected by various factors such as filler content, silanization, surface properties, and exposure and duration of force and temperature.[34] Some studies argue that high filler volume and small filler particle content contribute to wear resistance, while prepolymerized fillers increase the tendency to wear.[28, 35, 36] However, differences in filler particle shape, stiffness, and interparticle spacing make it difficult to establish a correlation between wear resistance, filler particle size, and filler volume.[19] With regards to the previous studies, Shinkai *et al*. reported that increased filler particle size resulted in lower two-body wear resistance, while filler loading had no significant effect on it.[37] Johnsen *et al*. suggested that effective wear resistance could be achieved with medium filler content, and particle size was not as important as previously reported.[38] Inconsistent outcomes may be due to differences in testing methods. Even though the filler content of the materials included in the current study is listed as follows; GrandioSo (% w/w: 89) > X-tra fil (% w/w: 86) ≈ Grandio Blocs (% w/w: 86) > Admira Fusion (% w/w: 84) ≈ Admira Fusion x-tra (% w/w: 84) > Tetric N-Ceram (% w/w: 80) > Tetric N-Ceram Bulk Fill (% w/w: 75-77). According to the result, group A+AF showed the maximum mean wear value, followed by groups AFX (4 mm) + AFB (2 mm), AFX(2mm)+AFB(4mm), G+GF, X (2 mm) + XB (4 mm), GB, X (4 mm) + XB (2 mm), TB (2 mm) + TFB (4 mm), TB (4 mm) + TFB (2 mm) and T+TF, respectively. Among BFCs, the higher wear resistance of methacrylate-based composites despite their lower filler content compared to ormocer-based bulk-fill composites can be attributed to their matrix structure and the photoinitiator Ivocerin, which increases the polymerization depth.

In bulk-fill resin composites, it is aimed to enable better light penetration and enhance curing depth by larger size of the filler content incorporated into the composition and the increasing translucency of the organic matrix.[39] It can be concluded that the increased size of filler particles compared to conventional composites has a negative effect on wear and roughness in bulk-fill composites such as X-tra fill and Tetric N-Ceram Bulk Fill. This can be explained by the presence of large depressions on the SEM images of the surface of the resin composite samples, indicating the separation of large filler particles.[40]

Sumino *et al*. compared the wear and flexural properties of flowable composites and universal resin composites and found that the mechanical properties of the former were superior.[41] For this reason, flowable composites were preferred as cavity liners during the restorations in the current study. The restorations were completed by capping the flowable composites with conventional composites. In order to investigate the indirect effects of material thickness on wear, cavities were restored using flowable BFC in two different thicknesses, 2 mm and 4 mm. The findings showed no statistically significant differences in wear resistance between groups AFX (4 mm) + AFB (2 mm) and AFX (2 mm) + AFB (4 mm); X (4 mm) + XB (2 mm) and X (2 mm) + XB (4 mm); and TB (4 mm) + TFB (2 mm) and TB (2 mm) + TFB (4 mm). Therefore, the hypothesis that groups restored with BFC in 2 mm and 4 mm layer thicknesses would exhibit similar two-body wear resistance was accepted.

The main limitations of this study were a) the use of a two-body abrasion test instead of a three-body abrasion device, and b) a partial simulation of the oral environment and chewing forces using a chewing simulator.

CONCLUSION

Within the limitations of this study, it can be concluded that:

1) Direct resin composite restorations and indirect composite CAD/CAM block restorations exhibit similar two-body wear behavior;
2) Comparison of ormocer and methacrylate-based resin composites revealed that wear behavior was not solely dependent on the matrix structure.
3) The wear resistance of bulk-fill composite restorations was not affected by the thickness of the layer.

Therefore, further *in vivo* and *in vitro* studies are necessary to improve the understanding of wear, a complicated process influenced by numerous factors.

Conflict of Interest

The authors had no conflict of interest to declare.

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