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ORIGINAL RESEARCH

Evaluation of wear resistance of opposed recent types of dental composites

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ABSTRACT

Background: A wide use of light-activated resin composites, in clinics, has increased recently due to the increased needs for esthetics teeth fillings. This *in vitro* study evaluated the wear resistance of various direct resin composites with different compositions.

Methodology: Composite samples were divided into three main groups: group A representing 20 discs of Filtek Z350 XT, group B representing 20 discs of Bio active restorative and group C (as antagonist composite) representing 40 discs of Filtek Z250 XT. A programmable logic controlled equipment was used to record the two body wear of tested composites. Images analysis software evaluated the tested samples surface topography. Statistical analysis was performed using student's *t*-test and Aasistat 7.6 statistics software.

Results: It was found that group B composite recorded statistically significant higher weight loss mean value; and in antagonistic composite groups, non-significant higher weight loss mean value than group A composite mean value. Also, it was found that group B composite recorded statistically non-significant higher roughness change mean value than group A composite mean value. It was found that group A antagonistic composite recorded statistically non-significant higher roughness change mean value.

Conclusion: A different wear resistance is observed for the two-body wear test, combining the results confirmed that the use of nanoparticles filled resin composites of value reduces abrasion of opposing surface especially with hard fillers like zirconia. A higher filler load in excess of 60 (vol %) results in increasing wear resistance although that softer glass particles filler was used.

Keywords: Resin composites, wear resistance, bioactive material, nanofillers, nanohybrid fillers.

Introduction

The wide use of light-activated resin composites has clinically increased recently due to the increased needs for esthetics teeth fillings [1]. Resin composites used in dentistry are composed mainly of three major components: resin matrix, inorganic fillers, and a silane coupling agent [2]. Recent dental resin composites have increased strength due to a higher filler content, filler synthesis improvement technology, organic matrices modification with subsequent decrease in its polymerization shrinkage that enhances resin composite's physical and mechanical properties [3,4].

Recently, most of the commercially available direct dental composites are microhybrid and nanofilled composites, as universal resin composites, for use in both anterior and posterior teeth [2].

Until now, dental composite restorations face two main clinical problems: delayed recurrent caries and fractured restoration [5–7]. Bagramian et al. [8] stated that 50%–70% of all clinically performed composite restorations were replaced due to failed restorations. So, there is a need to develop a bioactive composite with its capability of hard dental tissues healing [9,10]. Nowadays, nanoparticles are dispersed to synthesize dental composite restoration with subsequent increase in mechanical performance and esthetic appearance [11,12].

One of the most important mechanical properties of resin composites as teeth restorative materials is wear resistant, as it has a direct effect on shelf-life clinical serviceability of direct resin composite restorations [13,14]. Heintze [15] studied resin composite wear *in vivo* and *in vitro* and found that to achieve clinically long-lasting serviceability restorations of resin composites, it should be of high wear resistance.

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However, data about different commercially available resin composites wear rates with different compositions and various combination systems are still required. The aim of this *in vitro* study was to evaluate the wear resistance of different direct resin composites with different compositions.

Materials and Methods

The study was conducted in Qassim University Dental Clinic and Research Center. In the present study, three direct resin composites were tested and their manufacturers and compositions are presented in Table 1.

Composite samples were divided into three main groups: group A representing 20 discs of Filtek Z350 XT, group B representing 20 discs of Bio active restorative, and group C representing 40 discs of Filtek Z250 XT as an antagonist sample.

Twenty disc-shaped samples of each tested composite were taken (discs thickness was 2 mm and diameter was 10 mm). Each sample of tested composite materials was handled according to the manufacturer's instructions. Each prepared resin composite sample was molded in a cylindrical Teflon mold (10 mm diameter × 2 mm thick). Samples were backed with polyester. The mold top surface was covered with another polyester strip.

Filtek Z350 XT and bioactive restorative were cured for 40 seconds using a conventional halogen light-curing unit, which had a light intensity of 450–470 mW/cm^2 (Monitex, Blue LEX, LD-105, Taiwan) (Figure 1).

Forty disc-shaped samples of selected antagonist composite were taken (discs thickness were 10 mm and diameter were 5 mm). Each sample of selected antagonist composite material was handled according to the manufacturer's instructions (Figure 2).

A logically programmed controlled equipment was used to test two body wear of selected tested materials. This equipment is newly developed for stations multimodal ROBOTA chewing simulator integrated with thermo-cyclic protocol operated on servo-motor.

ROBOTA chewing simulator has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each of

Table 1. *Composition and manufacture of the tested materials.*

Material	Composition	Manufacture
Filtek Z350 XT	The resin contains Bis-GMA, UDMA, TEGDMA, and Bis-EMA. To moderate the shrinkage, the fillers are a combination of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4–11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4–11 nm zirconia particles).The inorganic filler loading is about 78.5% by weight (63.3% by volume)	3 M ESPE
Bio active restorative	66% by volume, reactive glass particles that mimic physical and chemical properties of natural teeth, shock-absorbing ionic resin component containing acidic monomer with antimicrobial properties. No Bisphenol A, no Bis-GMA, and no BPA derivatives'	PULPDENT Corporation
Filtek Z250 XT	Bis-GMA, UDMA, Bis-EMA, Surface-modified zirconia/silica filler particles. Nanohybrid composite with high filler loading, Sub-100 nm to micron-sized particles	3 M ESPE

Figure 1. *Prepared samples of tested composite materials.*

Figure 2. *Prepared antagonist composite samples.*

the chambers consists of an upper Jacob's chuck as tooth antagonist holder that can be tightened with a screw, and a lower plastic sample holder in which the specimen can be held. The composite specimens were embedded in Teflon housing in the lower sample holder (Figure 3). A weight of 5 kg, which is comparable to 49 N of chewing force was exerted. The repetition rate of the test is 10,000 times to clinically simulate the 1 month chewing condition, accompanying thermocycling according to the previous studies (Table 2) Jung et al. [16].

The weight loss of the specimens during test was measured by weighting using the electronic analytical balance (Sartorius, Biopharmaceutical and Laboratories, Germany) with an accuracy of 0.0001 gr to weight the difference in weight before and after 37,500 cycles. This electronic balance had a fully automated calibration technology and a micro weighing scale, the values of all the mounted composite discs samples were measured. Each mounted sample was well dried using tissue paper before weighing (Figure 4).

The optical methods tend to fulfill the need for quantitative characterization of surface topography without contact [17].

USB digital microscope with a built-in camera (Scope Capture Digital Microscope, Guangdong, China; Figure 4) photographed composite samples. This microscope was connected with an IBM compatible personal computer using a fixed magnification of 120×. The images with a resolution of 1,024 × 1,280 pixels were recorded. Areas of roughness measurements were specified and standardized by image cropping to 350 × 400 pixels using Microsoft Office Picture Manager.

Final images were analyzed for roughness areas, using WSxM software (Ver5 develop 4.1, Nanotec, Electronica, SL) [18]. Finally, 3D image of the surface profile of composite samples was recorded using a digital image analysis system (Image J 1.43U, National Institute of Health, USA) (Figure 5).

Student *t*-test was applied to detect significant difference between groups. Statistical analysis was presented using Aasistat 7.6 statistics software for Windows (Campina Grande, Paraiba state, Brazil). *P* values ≤ 0.05 were considered to be statistically significant in all tests.

Results

The mean values and standard deviations (SD) for wear measured by weight loss (gram) were recorded for both materials before and after wear simulation cycles, this is summarized in Table 3 and graphically represented in Figure 5. The wear recorded for the antagonistic cusps is also shown.

In experimental composite groups, it was found that group B composite recorded higher weight loss mean value (0.00592 ± 0.0018 gr) than group A composite mean value (0.00027 ± 0.0004 gr). The difference between

Table 2. *Selected wear teat parameters.*

Bath temperature change range: 5°C–55°C	Time of Dwell: 60 seconds
Movement vertically: 1 mm	Movement horizontally: 2 mm
Rising speed: 90 mm/s	Forward speed: 90 mm/s
Descending speed: 40 mm/s	Backward speed: 40 mm/s
Frequency of cycle 1.6 Hz	Weight per sample: from 5 kg
Torque; 2.4 Nm	

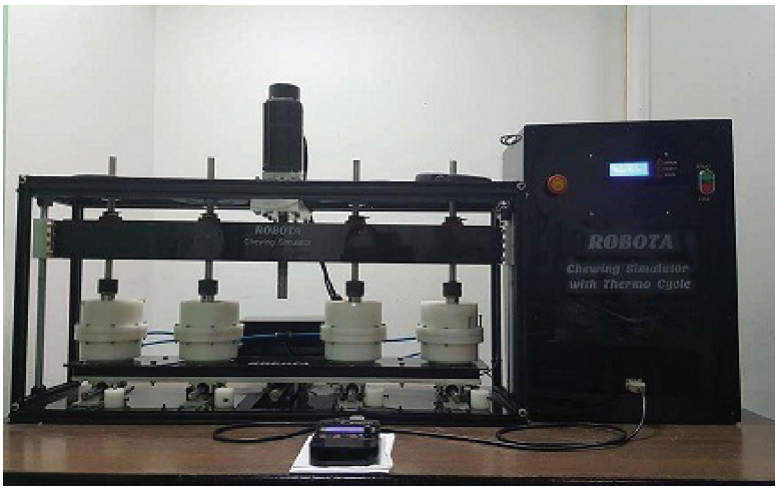

Figure 3. *Chewing simulator device ROBOTA.*

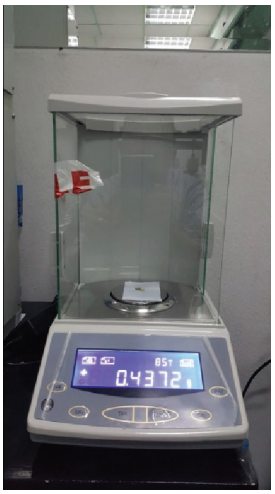

Figure 4. *Analytical balance.*

both groups was statistically significant as indicated by *t*-test ($p = 0.009 < 0.05$).In antagonistic cusp groups, it was found that group B antagonistic cusp recorded higher weight loss mean value (0.01 ± 0.002 gr) than group A antagonistic cusp mean value (0.0049 ± 0.005 gr). The difference between both groups was statistically non-significant as indicated by *t*-test ($p = 0.2947 > 0.05$) as shown in Table 4.

The mean values and SD for roughness measured by average roughness Ra in (μm) recorded on both materials before and after wear simulation cycles summarized in Table 5. The roughness recorded for the antagonistic cusps is also shown.

It was found that group B composite recorded higher roughness change mean value (0.00079 ± 0.0007 Ra) than group A composite mean value (−0.00067 ± 0.0003 Ra). The difference between both groups was statistically non-significant as indicated by *t*-test ($p = 0.09 > 0.05$).

It was found that group A antagonistic cusp recorded higher roughness change mean value (0.00077 ± 0.0006 Ra) than group B antagonistic cusp mean value (−0.00057 ± 0.0004 Ra). The difference between both groups was statistically non-significant as indicated by *t*-test ($p = 0.0537 > 0.05$) (Table 6).

Figure 5. *S capture digital microscope.*

Discussion

Development of bioactive dental composite restorations needs laboratory and clinical testing to allow prompt clinical properties' assessment. Wear is a loss of material by time and this important clinical properties should be evaluated. Many studies measured wear through variable occlusal forces and contact paths within and between subjects, and mentioned that wear can be represented by average values that remain relatively stable over time [19]. The present study tested the wear of various clinically used composites by subjecting them to *in vitro* simulations of mastication processes to estimate their stability under clinical conditions.

Based on the collected results, it was found that bioactive restoratives recorded statistically significant higher weight loss mean value than the nanocomposite mean value. It was observed that the tested composites are a different variety of particle sizes on nanoscale, they showed different wear rates. These findings are in agreement with McLundie and Patterson, who explained that these different wear rates may be attributed to difference in material properties. Particles type, volume by weight, and distribution play a major role to maintain the stability of the materials. Also, it was found that high filler content as hybrid composites shows better wear resistance [20].

Table 3. *Weight results (Mean values ± SD) for both experimental groups and cusp antagonist before and after wear simulation.*

Variables		Samples		Antagonistic cusp	
		Before	After	Before	After
Composite group	Group A	0.1577 ± 0.003	0.1572 ± 0.004	0.5524 ± 0.062	0.5475 ± 0.056
	Group B	0.1590 ± 0.001	0.15308 ± 0.006	0.5119 ± 0.0527	0.5019 ± 0.0516

Table 4*. Weight loss results (Mean values ± SD) for both experimental groups and antagonist as function of wear simulation.*

Variables		Samples			Antagonistic cusp		
		Mean ± SEM	95% CI		Mean ± SEM	95% CI	
			Lower	Upper		Lower	Upper
Composite group	Group A	0.00053 ± 0.0002	0.0001	0.001	0.0049 ± 0.005	−0.0064	0.01624
	Group B	0.00592 ± 0.0018	0.0018	0.01	0.01 ± 0.002	0.0048	0.0153
ANOVA	*P* value	0.009*			0.2947 ns		

CI, confidence intervals; SEM, standard error mean; ANOVA, analysis of variance; significant ($p < 0.05$) ns; non-significant ($p > 0.05$).

Table 5. *Roughness results (Mean ± SD) for experimental groups and cusp antagonist before and after wear simulation.*

Variables		Samples		Antagonistic cusp	
		Before	After	Before	After
Composite group	Group A	0.2557 ± 0.0009	0.2550 ± 0.0007	0.2555 ± 0.0013	0.2563 ± 0.001
	Group B	0.2555 ± 0.0008	0.2562 ± 0.0015	0.2567 ± 0.0008	0.2561 ± 0.0007

Table 6*. Roughness change results (Mean ± SD) for both experimental groups and antagonist as function of wear simulation.*

Variables		Samples			Antagonistic cusp		
		Mean ± SD	95% CI		Mean ± SD	95% CI	
			Lower	Upper		Lower	Upper
Composite group	Group A	−0.00067 ± 0.0003	−0.0016	0.0002	0.00077 ± 0.0006	−0.0006	0.0022
	Group B	0.00079 ± 0.0007	−0.0008	0.0024	−0.00057 ± 0.0004	−0.0016	0.0005
ANOVA	*P* value	0.091 ns			0.0537 ns		

CI, confidence intervals; ANOVA, analysis of variance; significant ($p < 0.05$) ns; non-significant ($p > 0.05$).

In antagonistic cusp groups, it was found that bioactive restoratives antagonistic cusp recorded statistically non-significant higher weight loss mean value than nano composite antagonistic cusp mean value. It seemed that Z250, the material used as antagonistic cusp showed high wear resistance due to its high filler load in excess of 60 (vol %). It coincides with Han et al. [21] study who reported that the nano hybrid composite resin, Z250, showed the lowest wear loss.

Xing and Li, and Turssi et al., [21–23] stated that the critical inter-particle spacing for dental composites is around 0.1–0.2 mm. For a fixed volume fraction of filler, a finer particle size for the composite results in less inter-particle spacing, more protection of the softer resin matrix and less filler plucking all of which lead to enhanced wear resistance for the material.

In the present study, it was found that silane coupling agent bioactive composite recorded statistically non-significant higher roughness change mean value than nanocomposite mean value. These findings may be attributed to different filler types as glass particles (tested bioactive restoratives) are easily leached than silica particles (Filtek Z350); while in antagonistic cusp groups, it was found that nanocomposite antagonistic cusp recorded statistically non-significant higher roughness change mean value than bioactive antagonistic cusp mean value. This can be a fact that silica particles are harder than the glass filler as mentioned before that during testing, dental composites wear resistance, and the type of fillers seem to be more considerable than the size for these resin composite materials. Many clinical researchers have mentioned that silica-filled composite has been recommended instead of a glass-filled composite that leaches more filler elements and degrades faster [24,25].

Conclusions

A different wear resistance was observed for the two-body wear test, combination of the results confirmed that use of nanoparticles filled resin composites of value to reduce abrasion of opposing surface especially with hard fillers like zirconia. A higher filler load in excess of 60 (vol %) results in an increase of wear resistance, although soft glass particles filler was used.

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List of abbreviations
CI Confidence interval
SD Standard deviation

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