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Comparison of Wear Resistance of Bulk Fill Flowable and Nanofilled Resin Based Composites against Enamel and Porcelain

Research Article

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Abstract

Objective: To evaluate and to compare the wear resistance of a newly introduced flowable composite material with a conventional resin-based nano composite against natural teeth (enamel) and porcelain crowns.

Materials and methods: 24 composite discs for each of two systems, Bulk fill Flowable (BF) and Supreme Ultra (SU), were made to 11 mm in diameter and 3 mm in thickness. All discs were scanned using lab scanner to generate three-dimensional (3D) virtual representations before undergoing the surface wear procedures. The discs for each material were divided into two subgroups (n=12/subgroup), one for testing with enamel and one for testing with porcelain. Each disc was then immersed in artificial saliva at 37°C and loaded into the testing apparatus to induce a simulated grinding force. Reciprocating, bi-directional movements were performed by the machine when the discs were opposing either enamel (human extracted teeth) or porcelain (porcelain crown duplicates of the extracted teeth) occlusal surfaces. All the discs were subjected to 105 newtons (10.7 kilograms) of force for 50000 bi-directional cycles during the griding test. Finally, after the surface wear tests were completed, each disc was scanned again using same lab scanner. The pre-test and post-test scans for each disc were compared within the computer software and the calculated volume (μm^3) of material wear was presented in root mean square (RMS). Independent-samples t-tests were used to analyze the data.

Results: Both materials demonstrated higher RMS values of surface volume wear when opposing porcelain than when opposing enamel, for both BF (mean [SD] = 140 [27] μm^3 with porcelain versus mean [SD] = 137 [9] μm^3 with enamel) and SU (mean [SD] = 135 [14] μm^3 with porcelain versus mean [SD] = 120 [9] μm^3 with enamel). There was a statistically significant difference between the two materials when tested against both teeth and porcelain ($p<0.05$).

Conclusions: The results suggest that: 1- porcelain crowns resulted in more composite material wear compared to enamel surfaces, 2- Supreme Ultra composite resin material exhibited less surface wear when compared to Bulk fill Flowable composite resin materials.

Keywords

Resin based composite; Bulk fill Flowable; Supreme ultra; Wear resistance

Introduction

Composite resins have been widely used since their introduction because of their excellent esthetic properties compared to other restorative material in the past [1]. Since decade ago, resin-based composites (RBCs) have been increasingly used for the restoration of posterior teeth. At the time, new compounds were developed with simplified handling procedures known as amalgam alternatives, such as packable composite resins [2]. In addition to their advantages with esthetic properties, they have the ability to bond to and preserve tooth structure, with little or no preparation necessary [3-5].

Composite resins are categorized into different types according to their chemical composition. Advances in filler technology have improved the properties of RBCs used in dentistry. These developments yielded to the introduction of nanohybrid and nanofilled RBCs [6,7]. Additionally, the arrival of the flowable composite resins has further diversified the market. These resins have lower filler volumes than conventional direct composite resin restorative materials [8]. Due to this lower filler volume these materials have decreased viscosity. However, they also have increased shrinkage and increased wear along with decreased strength [8,9].

To improve many of the aforementioned functional, mechanical, and biological properties, the size of filler particles incorporated into the resin matrix of commercial dental composites has continuously decreased over the years, from traditional to nano-composite materials [8-10]. Apart from changes in filler amount, shape, or surface treatment, advances in monomer structure or chemistry and modification of the dynamics of the polymerization reaction have also ushered in new generations of composites [11-16]. The latest flowable composites have increased filler content and are claimed to have increased mechanical properties; they thus are now also recommended for larger posterior restorations [17]. To further simplify the filling procedure (and to save precious chair time), the latest trend in composite technology is the development of flowable restorative composites that can be placed in bulk up to 4 mm in thickness [18-20].

Up until now, an incremental layering technique has been the standard to prevent gap formation from polymerization stress and to achieve adequate bonding of composite to tooth tissue [21-23]. In order to test whether or not one can discard the incremental steps and fill the cavity at once, the performance of contemporary bulk fill flowable composites for posterior restorations needs to be evaluated [24].

One of the clinical indications of this new flowable composite material is to for the filling of large cavities in the posterior teeth [17]. Restorative material that is indicated for use in the posterior teeth should have certain properties in order to have lasting clinical performance. One of the most important properties is wear resistance for the restoration to maintain its anatomical form, the interocclusal relationship, and the vertical dimension of occlusion.

In past years, one of the most common reasons for failure of resin-based material restorations was due to low wear resistance, which led to loss of anatomical form. Nowadays, efforts have been made in order to minimize this drawback. Most notably, filler size, volume, and shape have been modified. Although these efforts have proven success to some degree, low wear resistance is still considered to be a concern especially in large direct restorations or in patients with parafunctional habits [25-28]. Several studies have compared the wear resistance of composite materials and the results of those were controversial [29-33].

Diracoglu et al. [34], reported that the bite force for a patient with bruxism at the mandibular first molar tooth was up to 100 Newton, this magnitude of force could cause considerable wear in any given restorative material [34]. Therefore, these new composite materials should be evaluated carefully for wear resistance before they can be recommended for restoration of substantial cavities or use in patients with parafunctional habits, such as bruxism.

The aim of this study was to evaluate depth of wear resistance of the bulk fill flowable composite in comparison to the conventional RBC (nanohybrid) under two simulated clinical situations: one against human enamel and one against ceramic material. The null hypothesis was that there was no significant difference regarding the mean volume loss between the two composite resin materials using an in vitro two-body wear simulator protocol.

Materials and methods

Occlusal analogue preparation:

24 extracted, fully intact human maxillary third molars were collected from the oral surgery department at Tufts University School of Dental Medicine. Institutional review board approval of the protocol was not necessary for the use of the human-derived specimens. The selected teeth were free of restorations, caries, cracks and developmental defects. Surface debris and stains were removed with an ultrasonic scaler (Cavitron GEN- 119, SpsTM, Dentsply, York, PA). Following this, they were chemically disinfected by incubation in a 10% thymol solution for 24 hours and then stored in distilled water at room temperature

throughout the remainder of the study to prevent them from drying and becoming brittle. The roots of all of the selected teeth were notched for retention and embedded in self-curing acrylic resin (Coldpac, Motloid Company/ Yates & Bird, Chicago, IL) along their vertical alignment, with the cemento-enamel junction being positioned 1 mm above the top of the mounting template (Ultradent Product Co., South Jordan, UT). In order to fabricate a comparison group with the same criteria, the crown of each tooth was scanned using the E4D Dentist CAD-CAM system (Software Version 4.2, E4D Technologies, Richardson, TX) and then cloned and milled into porcelain crown (Empress CAD for E4D, Ivoclar Vivadent AG, Schaan, Liechtenstein) with an average cusp thickness of 3 mm. These porcelain crowns were also embedded in self-curing acrylic resin (Coldpac, Motloid Company/ Yates& Bird, Chicago, IL) along their vertical alignment. Each preparation was subsequently referred to as a cusp stylus.

Composite disc samples preparation

24 composite discs for each of the two systems, Filtek Bulkfill Flowable (BF) (3M, ESPE, St Paul, MN) and nanohybrid Filtek Supreme Ultra (SU) (3M, ESPE, St Paul, MN) composites, were made using a stainless steel mold. The discs dimensions were 11 mm in diameter and 3 mm in thickness. After light curing was completed, all of the discs were retrieved from the mold. To ensure surface smoothness and parallelism before the wear tests, all composite discs were finished with an applied force of 50 N at a speed of 350 rpm for 2 minutes with different grits of silicon carbide grinding paper (120, 240, 320, 600 grit; Buehler, IL) and Ecomet 250 (Buehler, IL) under running water.

The specimens were then cleaned for 1 minute with a steam jet (11706; Triton SLA, Lincoln, RI). After that, each disc was scanned using a lab scanner (Smart Optics Sensortechnik GmbH. Bochum, Germany) at baseline to generate three-dimensional (3D) virtual representations before undergoing the surface wear procedures. The discs for each material were randomly divided employing the statistical software package R (Version 2.13.1), into two subgroups (n=12/subgroup), one for testing with enamel and one for testing with porcelain, subgroup A was tested opposing enamel teeth and subgroup B was tested opposing porcelain teeth.

Grinding simulation

A clear plastic container was attached to the feed table of the testing apparatus; it contained artificial saliva (Bioten, GSK, Philadelphia, PA) that lubricated the loaded teeth and disc specimens throughout the testing procedures. The temperature setting was maintained at 37° C (normal body temperature) throughout the procedure (Figure 1).

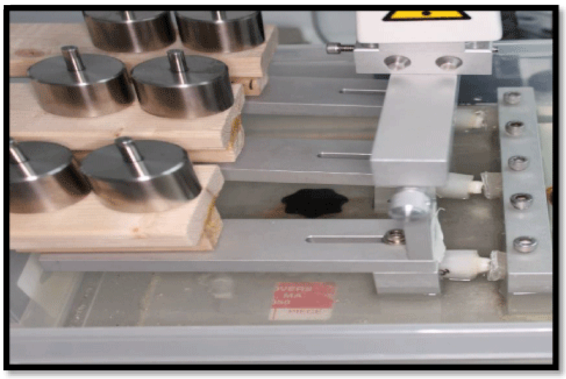

Figure 1: Grinding Simulator Machine.

To simulate grinding forces, the test was operated with 105 newtons (N) (10.7 kg) of force, which is the maximum occlusal force that is generated at the first molar region in patients with bruxism [10]. The tip of the cusp stylus was reciprocated 8 mm in each direction (average lateral excursion in the group of patients exhibiting a bruxism habit) [10] for 50000 cycles, while maintaining contact with the disc. The number of cycles was intended to resemble the wear equivalent to six months' worth of clinical performance [11] (Table1).

Table 1: Grinding Test Parameters

Test Parameter	Grinding
Sliding Movement	8 mm
Sliding Velocity	8 mm/1.5sec
Abrasive load per specimen	105 N (10.7 kg)
Number of cycles	50000
Hold Time	__

Wear quantification

The wear test procedure was performed in the form of two-body wear contact of reciprocating, bi-directional sliding to emulate grinding. In this test, a cusp stylus (either enamel or porcelain) contacted a flat surface [composite discs of either Bulk fill Flowable (BF), or Supreme Ultra (SU)] without lifting the stylus during the contact period. For wear simulation, a specifically designed, electro-mechanical, cyclic loading machine (TA-317C, Texture Technologies Corp., Hamilton, MA) was the apparatus for force application and control. After completion of the wear generating procedures, opposing surface wear on each specimen was determined by measuring the volume loss of each antagonist disc. Every acrylic disc was scanned three-dimensionally using same lab scanner that was used for the base line scans (Smart Optics Sensortechnik GmbH. Bochum, Germany).

After the scans were completed, base line scans and post-wear test scans files were obtained from the manufacturers in .stl format to measure the amount of volume loss between them (Figure 2). All comparisons were made using 3D digital inspection software, Quantify (Geomagic Inc., Research Triangle Park, NC), which works by minimizing distance criteria. The digital overlay was

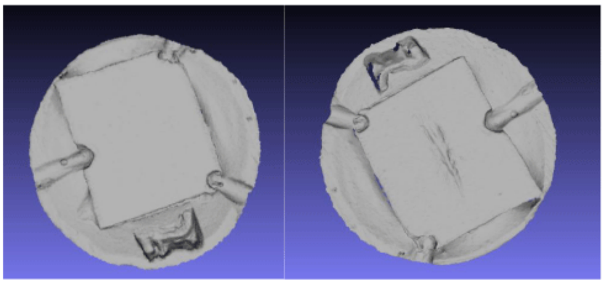

Figure 2: Disc Scan before and after Aging Test

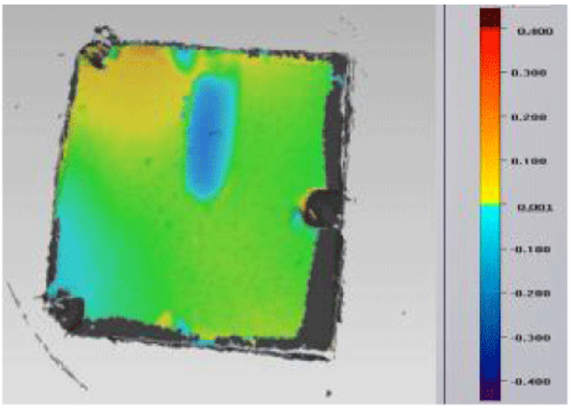

Figure 3: Evaluating the Wear with Geomagic Software

conducted with manual registration. Utilizing color-difference maps, the spatial discrepancies between the base line scan model and the post-wear test scan model were identified and analyzed. The test sensitivity was adjusted to detect differences from 1 to 500 micrometers (μm). The comparison between the two files was limited to the area of the disc surface (Figure 3). The Quantify software presented the results in numerical form (number of comparison points, minimum, maximum, root mean square, means, standard deviation and tolerance). The same operator handled all of the comparisons in the software.

Statistical analysis

A sample size of n=24 per group was adequate to obtain a Type I error rate of 0.05, a power greater than 99% for the comparison of enamel and porcelain, and a power greater than 99% for the comparison of the two material combinations. Descriptive statistics (means and standard deviations) were calculated by groups. Two sample t- test was utilized to assess statistical significance.

Results

The analysis of the data was accomplished by using SPSS software version 22.0, which includes descriptive analysis (Means, Standard Deviations, Standard Errors, Confidence Intervals), two sample t- test. Since the outcomes in all study parts were continuous variables with two testing groups, the data in this study was tested for significance two sample t- test.

Both materials demonstrated higher of surface volume wear when opposing porcelain than when opposing enamel, for BF (mean [SD] =140 [27] μm^3 with porcelain versus mean [SD] =137 [9] μm^3 with enamel) and for SU (mean [SD] =135 [14] μm^3 with porcelain versus mean [SD] =120 [9] μm^3 with enamel) (Table 2). There was a statistically significant difference between the two materials when tested against both enamel and porcelain ($p<0.05$). The results of this study suggest that conventional SU composite material performed better in terms of wear resistance than BF composite under the simulated clinical conditions (opposing enamel and porcelain).

Table 2: Means and Standard Deviations of Volume Loss for Each Group

	Tests	
	Grinding Test (Mean [SD])	
	Enamel (μm^3) n = 6	Porcelain (μm^3) n = 6
Filtek Bulkfill Flowable (BF)	137 [9]	140 [27]
Filtek Supreme Ultra (SU)	120 [8]	135 [14]

Discussion

In the present in vitro study, we compared the wear resistance between the nanohybrid resin-based composite material and bulk fill flowable composite material under two simulated clinical situations: one against human enamel and one against ceramic materials.

Based on our results, we found that the Bulk fill Flowable composite did exhibit less wear resistance than the Supreme Ultra, against both human enamel and ceramic materials. The differences between the two materials altogether were statistically significant, according to two samples t-test analysis. Thus, the null hypothesis was rejected in favor of the alternative hypothesis.

The results of this study displayed a higher RMS value of volume wear when the composites opposed porcelain crowns compared to natural teeth (enamel). In this study, IPS Empress Porcelain was implemented and it has been reported to cause the greatest opposing enamel wear when compared to gold alloy and processed composite material [13,14]. This would explain the difference in numerical data and resultant composite material wear in comparison with natural teeth (enamel). In terms of composite material comparison, the Supreme Ultra composite materials exhibited the lowest RMS of volume loss, which can be attribute to the larger filler particle size that could resisted the wearing forces.

The result of this study were compared to those of the previous studies, Nakayama et al. [29], has test the wear resistance of flowable composites and traditional composite materials against human enamel and found there is no significant difference between them, these findings are in disagreement with the findings in this study, possibly because their aging and wear simulation were not similar to the protocol in this study. Nakayama et al. tested the samples a under different applied force value and number of wearing cycles.

Baladhandayutham et al. [30], Kummer et al. [31], and Kojic et al. [32], studies compared wear resistance of different composite resin materials and found Supreme Ultra composite was the best material in terms of wear resistance. These finding are in concordant with the results of this study, in which the SU was better than the BF composite. However, the aforementioned studies did not use BF as a testing group. Nevertheless, the wear testing methodology in all the previous mentioned studies was not the same, since those investigations evaluated the wear in one dimension (vertical amount of material loss opposing the wear cusp), whereas in this study the wear was evaluated in a three dimensional manner using computer software.

In this study, extracted human third molar teeth were cloned into porcelain crowns, specifically IPS Empress ceramic. The occlusal anatomy was matched among the groups opposing natural and porcelain teeth. A specially designed, electro-mechanical, cyclic loading machine was used to simulate surface wear. A reciprocating sliding movement, without impact, was selected to simulate grinding behavior. A load of 105 N (10.7 kg) was selected for this study because it has been reported to be the maximum bite force at the first molar region in patients with bruxism [10].

The test distance was set at 8 mm because it has been reported to be the average distance of lateral excursion in patients with bruxism [10]. The time period during the grinding test was set at 1.5 seconds for each cycle, as this has been reported to be the time span of each electromyography (EMG) burst, which indicated muscle movement during bruxism [10]. 50000 bi-directional cycles were used in the grinding test to simulate six months' worth of aging which is the average time for patient re-care visits after the initiation of treatment. As mentioned earlier, the number of cycles, duration of each cycle, and the distance of movement are different in most of the wear simulation studies within the literature, which can to lead to variability of results throughout studies.

The amount of surface wear was measured as volume loss based on 3D scanning comparison software. Baseline and post-test scans were compared and the volume loss was reported as RMS per specimen. Compared to conventional wear quantification methods, 3D comparison has been reported to be the most effective method to measure wear.[12] It is preferred for measuring wear because it is quantitative, accurate, provides storable 3D databases that can be compared to other 3D databases, and is applicable to both in vivo and in vitro settings.

The limitations of this study include that it was an in vitro study that lacked exact intraoral environment parameters. For instance, the teeth were extracted third molar teeth with intact occlusal surfaces, as opposed to teeth with common wear facets from patients with bruxism. Moreover, the CAD-CAM-generated porcelain crowns were polished after milling without glazing. Surface glaze can contribute to less surface roughness. This roughness potentially causes increased friction and the prosthesis becomes prone to volume loss. Although on the day of fitting several occlusal adjustments can alter the surface glaze. In addition, porcelain crowns have been reported to exhibit loss of surface gloss and surface roughness after a few months of use within the intraoral environment [16]. The test was performed under a pool of artificial saliva, with no change in salivary flow, while in normal oral conditions the salivary flow rate varies from day to night. Another limitation of the study was overlooking an evaluation of the cusp tip before and after the testing to account for the wear effect of the two composite materials on the opposing cusps surfaces (enamel and porcelain).

The sample size in this study may seem to be too small however the sample size calculation was done by using the results of an earlier pilot study (n=3) using the same composite systems and methodology. This was a more reliable and scientifically sound method to calculate appropriate sample size for this study, as opposed to relying on the results of previous studies that were completed in varying conditions. The sample size was calculated by a professional statistician, who worked with nQuery software version 17.0. The sample size of n=6 per group was calculated to be sufficient enough to obtain a power of 99% and Type I error rate of α=0.05.

With this study's limitations in mind, further laboratory studies, randomized clinical trials, and prospective clinical studies are needed to scrutinize the wear resistance of the composite systems that were examined. More studies are needed to evaluate the degree of composite material wear under more clinically relevant parameters.

Conclusions

The results suggest that: 1- porcelain crowns resulted in more composite material wear compared to enamel surfaces, 2- Supreme Ultra composite resin material exhibited less surface wear when compared to Bulk fill Flowable composite resin materials.

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