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An In Vitro Assessment of Wear Rate of Various Bite Turbo Materials

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Introduction:

In the practice of orthodontics, there are several indications for opening a patient's bite. Fixed orthodontic appliances, although relatively small, have the potential to interfere with a patient's occlusion and ability to function. Such interferences can lead to significant abrasion of the dentition or result in debonding of brackets. Additionally, certain malocclusions, such as anterior crossbites, may require bite-opening to facilitate needed orthodontic movements[1]. Historically, fixed and removable appliances made of metal and acrylic have been utilized to temporarily open the bite to achieve treatment objectives; however, such appliances require lab fabrication and patient compliance. As bonding materials and methods have improved, many orthodontists have turned to a variety of resins and glass ionomers as a convenient and predictable method to open a patient's bite. These bonded attachments are commonly referred to as "bite turbos".

Due to their ease of use and unique coloration, many clinicians prefer to fabricate bite turbos from band cements and acrylic gels[2]. Fluoride release from glass ionomers may also provide the added benefit of caries resistance[3-6]; however, some authors have suggested surface characteristics may actually increase the risk of caries [7, 8]. Although the bond strength[9-11], solubility[12], and potential toxicity[13, 14] of various orthodontic adhesive have been evaluated at length, studies have focused on the materials being used for their intended purpose to retain bands and appliances.

To date, very little research has been focused on the "off label" usage of adhesives to temporarily open the bite. Unlike traditional occlusal restorations that are meticulously adjusted to avoid disruption of the patient's function, bite turbos are placed with the intent to isolate points of occlusal contact to specific teeth. Depending on treatment objectives and the patient's occlusion, bite turbos are often placed on the functional cusps of first molars or the lingual aspect of central incisors[2]. Due to the non-traditional utilization and placement of orthodontic cements, several researchers have set out to evaluate the unique demands imposed on the material itself[15] and the effects of bite turbos on masticatory function[16, 17].

The purpose of this study is to continue to add to the body of knowledge regarding resin bite turbos by assessing the rate of wear of several popular bite raising materials. This knowledge may help clinicians improve placement techniques and provide guidelines for needed thickness of material.

Materials and Methods:

This study was a laboratory based in vitro study carried out by the Orthodontic Department at the United States Air Force Post Graduate Dental School with association to the Uniformed Services University.

Study Design

For this study, three popular bite opening materials were investigated: 1) Triad Gel (TG) (Dentsply Sirona, York, PA), 2) Transbond Plus Light Cure Band Adhesive (TB)(3M, Monrovia, CA), 3) and Ultra Band-Lok (BL)(Reliance, Itasca, IL). Triad Gel is an acrylic resin consisting primarily of methacrylate with approximately 10% silica filler particles. Both Transbond Plus and Ultra Band-Lok are polyacid-modified composite resin (compomers) with silica and quartz filler materials. Ten samples of each material underwent wear testing. The initial research design was to test the samples using the ACTA wear machine, which has been successfully used for the purpose of simulating two- and three-body wear[18-20]. Due to the COVID-19 pandemic, access to the ACTA wear machine was limited and our protocols had to be redesigned to incorporate machinery that was readily available. The Automated Brushing Machine from Sabri Dental Enterprises (Sabri Dental Enterprises, Downers Grove, IL) was chosen to simulate wear. Custom jigs containing the samples and antagonists were retrofitted to the Automated Brushing Machine. The jig containing the antagonist was fabricated using Accura ClearVue with the ProJet 6000HD printer (3D Systems, Rock Hill, SC) and the sample jig was fabricated using

VeroWhite Plus with the Connex3 Objet260 (Stratasys, Eden Prairie, MN). The antagonist was a 1.2mm diameter stainless steel ball stylus (Fiskars Brands, Inc., Madison, WI) with a total length of 18.5mm. The stylus was secured in the jig using cyanoacrylate. In total, 30 antagonists were fabricated, one for each sample to be tested. Each antagonist was labeled and designated to a specific bite turbo sample. All bite turbo materials were placed in their respective jigs per manufacturer's guidelines. Photoactive materials were placed and cured incrementally using the Valo cordless curing light (Ultradent, South Jordan, UT) for 12 seconds at 3200 mW/cm^2. Following photopolymerization, all samples were sanded with 180 grit SiC paper to achieve a uniform surface.

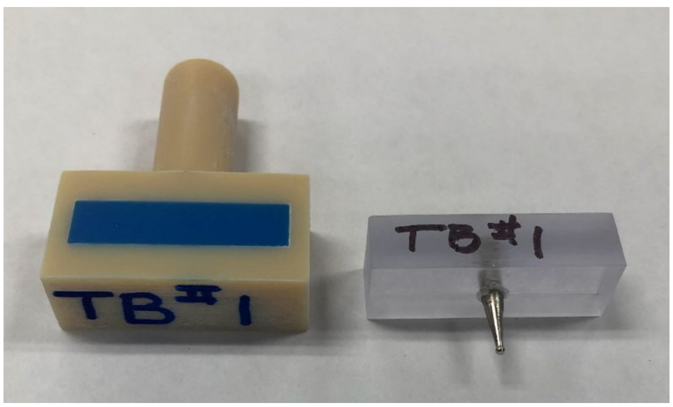

Figure 1. Specimen jig (left) and antagonist jig with stylus antagonist (right).

Samples were scanned using the 3Shape R2000 Orthodontic Scanner (3Shape, Copenhagen, Denmark) prior to wear testing to obtain a baseline. Localized, two-body wear simulation was subsequently performed within distilled water for 4,500 cycles at 60 RPMs and 49 Newtons (5000 grams) of force. Following the initial iteration, a progress scan was obtained. Volumetric loss was calculated by superimposing the initial and progress scans, isolating the site of wear, and utilizing Boolean Subtraction to determine the volume (mm^3) of the area of interest. Following this analysis, an additional 9,000 cycles were performed and final scans were obtained and analyzed to determine total volumetric loss.

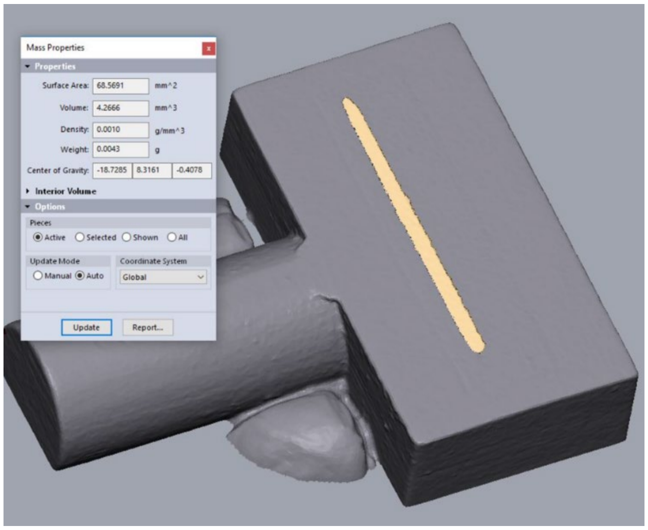

Figure 2. Superimposition of initial and final scan with area of wear isolated.

Progress and final values for volumetric loss were analyzed using a univariate repeated measures analysis of variance (ANOVA) and Tukey's post hoc test. Significance was set to $p<0.05$. Statistical analyses were performed using IBM SPSS version 24 (IBM, Armonk, NY).

Results:

Table 1. Average values of volumetric loss at T_1 following 4,500 cycles.

Material	Mean (mm^3)	Std. Deviation	N
Ultra Band-Lok (BL)	0.2865	0.2630	10
Transbond Plus (TB)	0.6278	0.3846	10
Triad Gel (TG)	1.6867	0.8666	10

Table 2. Average values of volumetric loss at T_2 following additional 9,000 cycles.

Material	Mean (mm^3)	Std. Deviation	N
Ultra Band-Lok (BL)	0.7384	0.8509	10
Transbond Plus (TB)	1.1527	0.3904	10
Triad Gel (TG)	4.1012	0.9045	10

Table 3. Average values of total volumetric loss at T_2 with outliers removed.

Material	Mean (mm^3)	Std. Deviation	N
Ultra Band-Lok*	0.4939	0.3788	9
Transbond Plus	1.1527	0.3904	10
Triad Gel*	3.9087	0.5906	9

*Outliers removed

For this study, 3-dimensional scans of each sample were captured at 3 different timepoints: an initial scan to obtain a baseline (T_0), a progress scan to assess wear following 4,500 cycles (T_1), and a final scan to assess total volumetric loss following an additional 9,000 cycles (T_2). Table 1 contains the results following analysis of the progress scans. At this point the TG group demonstrated the greatest amount of wear, followed by the TB group, and finally the BL group. This same order of wear was maintained when assessing total volumetric loss, as can be seen in Table 2. A Shapiro-Wilk test revealed a lack of normality within the BL group. Through further investigation two significant outliers were identified, one in the BL group and one in the TG group. Each group achieved a normal distribution following removal of these extreme data points. An additional ANOVA was completed and the results can be seen in Table 3. Following this adjustment, a significant difference ($p<0.05$) in the rate of wear was noted between each type of bite turbo material.

Discussion:

The use of bite turbos has proven to be an effective treatment adjunct in the field of orthodontics. A variety of bite opening materials have been utilized to achieve treatment objectives and avoid potentially harmful interferences; however, many of these materials were not designed with occlusal forces in mind. At this point, little is known regarding the rate of wear of popular bite opening materials.

One important consideration when selecting a bite turbo is the composition of the product. A material's filler content will influence its hardness and susceptibility to abrasive forces. Triad Gel is mostly composed of methacrylate with approximately 10% silica filler content. In comparison, Ultra Band-Lok's filler content is 65% barium-silicate glass with 4% silica by weight and Transbond Plus Band Cement contains 77.5% silane treated silica. With this in mind, the relatively rapid wear observed in the Triad Gel group is in harmony with the composition of the material. On the other hand, Ultra Band-Lok and Transbond Plus have similar filler content, thus the observed rate of wear was much less in these groups. The unique proprietary formulations of Ultra Band-Lok and Transbond Plus likely explain the observed difference in wear rate between these groups.

It is important to recognize that a relatively rapid rate of wear does not equate to an inferior bite turbo material. Instead; an orthodontist should evaluate the needed treatment mechanics, patient characteristics, and location of bite turbo to select a material that will best serve to open the bite. An understanding of the rate of wear may also assist in determining the amount of material needed to maintain bite opening between appointments. Another consideration is with increased hardness comes the increased possibility of abrasion to opposing dentition. Further research assessing abrasion between bite turbo materials and enamel would be beneficial.

In vivo, there are many factors that can influence the amount, frequency, and types of forces experienced by a bite turbo. A patient's habits and phenotype may influence bite force and subsequent wear. Placement technique and location of turbos can also play a role in abrasion of the material. The intent of this study was not precise replication of physiologic force; instead, the objective was to standardize force, frequency, and environment between samples. Several devices are currently available to simulate wear of dental materials. The initial design of this study was to utilize the ACTA wear machine; however, the COVID-19 pandemic precluded access to the ACTA wear machine. For this reason, a modified brushing machine was selected as an alternative modality to simulate wear.

Every effort was made to standardize the process to ensure a uniform environment for each sample. An antagonist was assigned to each specimen to account for potential abrasion of the antagonist itself. Each iteration required a meticulous set up to distribute forces equally. Despite attention to detail, some samples experienced a significantly different amount of wear when compared to the group. Although the source of these outliers is difficult to identify, one potential contributing factor is that multiple specimens underwent wear testing simultaneously. Additionally, multiple iterations were performed, which required recalibration of the setup and increased the opportunity to introduce error. Any slight discrepancy in the system at any point of the simulation may result in disproportionate wear. The mounting hardware and the antagonist are potential points of failure, although no catastrophic event was noted during the course of testing. Fortunately, these irregularities only affected 2 of the samples tested.

Conclusion:

In this study simulating two-body localized wear of three popular bite turbo materials, a significant difference in the rate of wear was observed between each of the materials tested. It was found that the wear rate was as follows: TG>TB>BL. It is recommended that this study be repeated using ISO approved methods of wear simulation to verify the results.

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