


Performance of Different Orthodontic Brackets after Exposure to Dietary Components: An *in Vitro* Pilot Study

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Abstract

Introduction: The aim of this study was to determine whether there was a significant difference in shear bond strength between metal and ceramic brackets when exposed to acidic dietary components (beverages) and to observe the chromogenic potential of each *in vitro*. **Methods:** Metal and clear orthodontic brackets were placed on extracted maxillary second premolars and exposed to select beverages three times daily for four weeks. Shade was taken using a colorimeter device at seven intervals and the shear bond strength of each bracket was recorded. **Results:** There was a variable change in tooth shade with respect to the various beverages in which they were submerged. Coffee and Dr. Pepper had the most pronounced change, whereas Red Bull and water produced little to none, respectively. Compared to controls, brackets submerged in coffee had the greatest reduction in shear bond strength, followed by Dr. Pepper, then Red Bull. Overall, clear brackets showed higher shear bond strength than metal brackets. **Conclusion:** Acidic dietary components have a negative effect on the shear bond strength of orthodontic brackets, and more pigmented beverages have a higher chromogenic staining potential.

Keywords

Bracket, Shear Bond Strength, Orthodontics, Tooth Shade

1. Introduction

In orthodontic treatment, esthetic concerns are as important as functional demands [1]. Fixed orthodontic appliances have been found to cause tooth color

changes, and high consumption of acidic beverages may result in increased enamel and dentin susceptibility to exogenous acids originating from those beverages, such as energy drinks [2] [3]. An increase in the consumption of low pH soft drinks, especially among teenagers, has been observed [4]. Frequent consumption of carbonated acidic drinks provides a regular supply of corrosive agents in addition to other contributors of acid to the oral cavity, such as fluoride-containing products like toothpaste and mouthwash. Clinically, this is problematic as an acidic environment increases the corrosion susceptibility of certain metals, especially titanium [5]. Numerous tests have been used to investigate the *in vivo* and *in vitro* color stability of dental materials for artificial aging [6] [7] [8]. The effect of dietary components on the seal of orthodontic adhesives demonstrated areas of adhesive loss from the enamel after exposure to the low pH dietary components or food-simulating media [9] [10]. It has been shown that acidic soft drinks have a negative effect on bracket retention against shearing forces [11].

The present *in vitro* pilot study aimed to evaluate the performance of two types of orthodontic brackets (metal and ceramic) with respect to shear bond strength (SBS) when exposed to various dietary components in addition to the chromogenic potential of common acidic, pigmented beverages.

2. Methods

Metal and clear orthodontic brackets (3 M Unitek) were bonded to 24 extracted maxillary second premolars (a set of 12 for each type of bracket, $n = 12$) using Greenglo cement (Ormco Corp.). Inclusion criteria consisted of teeth with wholly sound tooth structure without evidence of fracture or enamel defects. Three dietary solutions were selected by an informal survey of dental students that chose their favorite soft drink, Red Bull variety, and Keurig K-cup coffee brand/roast. The most popular choices were Dr. Pepper, Red Bull classic, and Starbucks medium roast K-cups with tap water used as a control. The pH of each solution was as follows: Dr. Pepper (2.88 ± 0.04), Red Bull (3.43 ± 0.01), Starbucks medium roast (5.11 ± 0.05), and tap water (average of 7.9) [12] [13]. We chose to use tap water rather than artificial saliva due to the variability of formulas by brand and the introduction of an additional set of confounding variables that would further complicate data interpretation [14]. The bonded teeth were ultimately divided into eight groups: Three active groups and one control for both metal and clear brackets ($n = 3$). To avoid any bias and ensure randomization and blinding, specimens were number-coded and randomly selected for the tests. Teeth were immersed in each dietary solution and water for 15 minutes three times daily at different intervals to simulate an *in vivo* environment and were stored in regular water at room temperature (23°C) between immersions. For each immersion, a new bottle was opened and the coffee samples were freshly brewed, keeping in line with standard preparation for consumption.

For tooth shade, an electronic colorimeter (VITA Easyshade V) was used. Re-

cordings were taken three times at three locations: occlusally at the center of the central groove, and interproximally at the center of the mesial and distal surfaces. Each recorded reading in **Table 1** was the average of nine readings taken for each tooth immediately after immersion. In this case, because shade is not easily quantifiable, the term “average” refers to the reading that was reproduced the most frequently from the nine instances. Readings of the classic VITA shade and 3D VITA shade were recorded immediate post-bonding, after 24 hours, 72

Table 1. Average readings of the classic VITA shade and 3D VITA.

Teeth with Metallic Bracket	Post placement	24 Hours	72 Hours	1 Week	2 Weeks	3 Weeks	4 Weeks
WM1	5m1, C4	5m1, C4	5m1, C4	5m1, C4	5m1, C4	5m1, C4	5m1, C4
WM2	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4
WM3	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5	4L2.5, A3.5	4L2.5, A4
DrM1	5m2, C4	5m2, C4	5m2, C4	5m3, C4	5m3, C4	5m3, C4	5m3, C4
DrM2	5m1, C4	5m1, C4	5m1, C4	5m2, C4	5m2, C4	5m3, C4	5m3, C4
DrM3	4m3, C4	5M2, C4	5M2, C4	5m3, C4	5m3, C4	5m3, C4	5m3, C4
CM1	2m3, B3	4r2.5, A4	4M3, C4	5M3, C4	5M3, C4	5M3, C4	5M3, C4
CM2	5m1, C4	5m2, C4	5M3, C4	5M3, C4	5M3, C4	5M3, C4	5M3, C4
CM3	4m3, A4	5m1, C4	5M2, C4	5M2, C4	5M2, C4	5M2, C4	5M2, C4
EM1	4L2.5, A4	4L2.5, A4	4M2, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4
EM2	2r2.5, C3	4m1, C3	4M1, C3	3M1.5, C4	4M1, D4	4R1.5, A4	4R1.5, D4
EM3	4m1, C3	5m1, D4	5M1, D4	4R1.5, D4	4R2.5, A4	5M1, C4	5M2, C4
Teeth with Clear Bracket	Post placement	24 Hours	72 Hours	1 Week	2 Weeks	3 Weeks	4 Weeks
WC1	5m2, C4	5m2, C4	5m2, C4	5m2, C4	5m2, C4	5m2, C4	5m2, C4
WC2	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4	4M3, A4
WC3	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5	3M3, A3.5
DrC1	3m3, A3.5	3m3, A3.5	4M3, A4	4M3, A4	4M3, C4	4M3, C4	4M3, C4
DrC2	4m3, A4	4m3, A4	5M2, C4	5M3, C4	5M3, C4	5M3, C4	5M3, C4
DrC3	3m3, A3.5	4m3, A4	4M3, A4	4M3, A4	5M2, C4	4M3, C4	4M3, C4
CC1	3m3, A3.5	4m3, A4	5M2, C4	5M2, C4	5M3, C4	5M3, C4	5M3, C4
CC2	4m3, A4	4m3, A4	5M3, C4	5M3, C4	5M3, C4	5M3, C4	5M3, C4
CC3	3r1.5, C3	5m1, C4	4M3, C4	4M3, C4	5M2, C4	5M2, C4	5M2, C4
EC1	4m1, A4	4m2, A4	4M2, A4	4M3, A4	4M3, A4	5M2, C4	5M2, C4
EC2	4m3, A3.5	4m3, A3.5	3M3, A3.5	3M3, A3.5	4M3, A4	4M3, A4	4M3, A4
EC3	2m3, B3	2m3, B3	2M3, B3	3M3, B4	3M3, B4	3M3, B4	2M3, B4

*WM: Metal bracket immersed in water; DrM: Dr. Pepper; CM: Coffee; EM: Red Bull; *WC: Clear bracket immersed in water; DrC: Dr. Pepper; CC: Coffee; EC: Red Bull.

hours, seven days, 14 days, 21 days, and 28 days. After the final color data was collected, the roots of the samples were cut, and the coronal portion of the sample was mounted in acrylic resin, leaving the buccal side with bonded brackets exposed. The shear bond strength was recorded for each bracket using an Ultra Tester machine (Ultra Tester™ Bond Strength Testing Machine) in MPa. The shear bond strength was analyzed using two-way ANOVA and post-hoc Tukey tests.

3. Results

The three dietary components had a variable change in the shade of the teeth for both metal and clear brackets after four weeks of immersion. Teeth immersed in Dr. Pepper and coffee, predictably, had the most significant eventual changes in color, measuring at the darkest classic Vita shade (C4) within 3 days 83.33% of the time (Table 1), with coffee samples exhibiting the quickest change. Red Bull, which has more value (lightness) than Dr. Pepper or coffee, presented less shade change over time. No significant changes in the shade were observed for teeth immersed in water over the 4-week period (Table 1). Data extracted from shear bond strength testing is represented in Figure 1. Results showed that metal brackets had a lower shear bond strength compared to clear brackets, where the difference was statistically significant according to both two-way ANOVA ($p = 0.036$) and Tukey ($p = 0.015$) analyses. The overall mean bond strength for the clear and metal brackets (21.68 MPa and 13.06 MPa, respectively) is reflective of previously described values in a similarly modeled study utilizing extracted premolars [15]. For each set (metal brackets and clear brackets), the dietary solutions appeared to follow a trend empirically, with coffee-soaked teeth exhibiting the lowest shear bond strength, followed by Dr. Pepper, then Red Bull; however, ANOVA analysis showed the differences between intra-bracket type samples (e.g. metal in coffee vs. metal in Red Bull) and between beverages as a whole (e.g. all brackets in coffee vs. all brackets in Red Bull) were insignificant ($p > 0.05$).

4. Discussion

Clinically, the stability of orthodontic bracket bond strength and esthetics are of

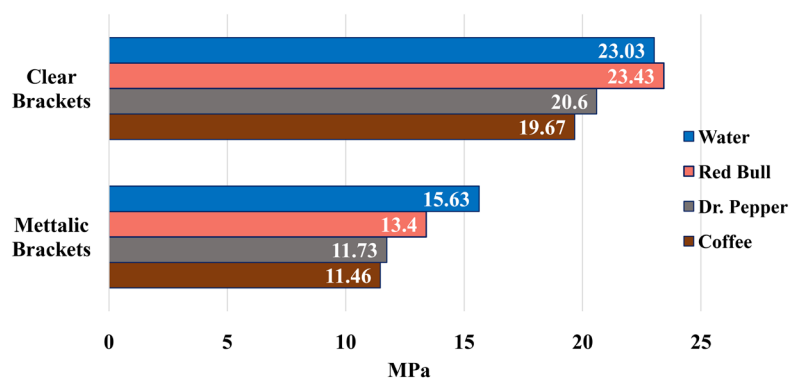


Figure 1. Mean shear bond strength (MPa) across all samples after 4 weeks of immersion.

primary concern for both patients and practitioners. The present results showed that there are significant changes in the performance of different orthodontic brackets when exposed to acidic beverages. Impaired shear bond strength of orthodontic brackets and enamel color degradation are considered clinical shortcomings in the oral environment.

There are several causes of the discoloration of enamel. Dietary beverages and colored mouth rinses can cause external discoloration. Stains can be distinguished either visually or by using a colorimeter; however, human eye sensitivity in detecting small color differences is restricted, and the determination of visual color comparisons is subjective. For that reason, an electronic colorimeter was integral to our efforts by offering consistency and objectivity to observing changes over time measured. In the present investigation, teeth immersed in Dr. Pepper and coffee showed the most significant color changes. The current findings come into agreement with the investigation by Faltermeier *et al.*, which showed that unsatisfactory color stability of the orthodontic adhesive system was noticed after 72 hours of exposure to pigmented dietary components such as tea [16]. Whether there was an influence from the adhesive or corrosion of the titanium brackets in this study remains unclear. For the purposes of this study, the exposure time was set to up to four weeks (28 days), as in a previous investigation it was noted that dental composite color difference was determined mainly after four weeks [17]. While composite was not a factor in our study, this timeline assisted in guiding our investigative framework. The results are in agreement with previous research which revealed that certain diet components, such as coffee, may cause severe staining of resin base esthetic restorative materials when compared with other dietary components [18] [19].

It has been concluded that acidic, low pH drinks provide a regular supply of corrosive agents for metallic orthodontic appliances and that the acidic environment will increase the corrosion susceptibility of certain metals, such as stainless steel and titanium brackets [5] [20] [21]. An *in vivo* study showed that the titanium and steel brackets undergo degradation in acidic conditions below pH 3.5. The consumption of low pH drinks can play role in reducing the oral environment pH which will influence sensitivity of metal brackets to the corrosive influence [21].

Material properties such as bond strength play some essential roles in the survivability of orthodontics brackets. Ceramic brackets bond to the tooth by forming chemical and mechanical bonds. The present shear bond strength results showed that metal brackets recorded the lowest shear bond strength. This finding comes into agreement with previous studies that reported that the mean SBS of ceramic brackets was superior when compared with that metallic brackets [15] [22]. This could be due to the corrosive influences of the dietary components and/or the erosive effect of the dietary component on enamel.

It is tempting to associate an overall trend with respect to the pH of each dietary solution; however, an additional factor to consider would be the effect of

solution temperature in combination with pH on the enamel bond. According to our data, the clear brackets had a higher shear bond strength compared to metal brackets. It was surmised that this was due to the integration of the bonding material with the ceramic. The preparation of the ceramic surfaces leads to the formation of porosities and micro-pores, which increases the ceramic brackets' bond strength. Orthodontic brackets are continuously exposed to the oral environment and compounds that may affect their bonding integrity. While our results seemed to show evidence of a trend empirically, they were, in this regard, not significant for our sample size and further study is needed in this matter. As this investigation was conducted in an *in vitro* environment, further study also needs to be conducted with the consideration of oral health habits such as tooth brushing and the presence of fluoridated toothpaste that may have an impact on the outcome.

5. Conclusion

Within the limitations of this study, different acidic dietary components tend to affect the color stability of teeth with bonded brackets. Additionally, the clear orthodontic brackets had a statistically significant higher shear bond strength compared to metallic brackets after four weeks of immersion in the selected dietary components. Further study is needed to confirm the findings of this pilot study.

Authors' Contributions

NHA and TA conceived the protocol; NHA, TF and TA revised the manuscript; TF, SA, JL and NHA contributed to data acquisition and interpretation; JL performed the statistics. All authors read and approved the final version of the manuscript.

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Ethics Approval and Consent to Participate

No ethical approval was required for the study since the Institutional Research Board (IRB) of UNLV classified it as an exclusion review (laboratory research).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

ANOVA: Analysis of variance; SBS: Shear bond strength.