Influence of the Use of Remineralizing Agents on the Tensile Bond Strength of Orthodontic Brackets

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Article

Keywords: Caseins, fluorides, orthodontic bracket, tensile strength, dental enamel

Posted Date: May 17th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1544803/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on January 10th, 2023. See the published version at https://doi.org/10.1038/s41598-023-27390-0.
Abstract

This study aimed to evaluate the influence of the use of remineralizing agents on the tensile bond strength. The study sample consisted of 80 recently extracted molars, which were randomly divided into two groups (n = 40): the first group (FG), which used fluoride varnish, and the second group (RG), which used Recaldent tooth mousse. The buccal surface of each tooth was divided into experimental and control. Brackets were bonded to both surfaces and were submitted to a tension test according to the study protocol. Tensile bond strength (TBS) and the amount of adhesive remnant (ARI) were assessed. A statistically significantly lower mean of TBS compared to the control group was found only in the FG1 group (p <0.001), and no significant difference was found between the other groups. The FG1 group showed a significantly higher amount of adhesive residue on the bracket (p <0.001) compared to the control group. No significant difference was found between the other groups.

In conclusion, bonding brackets immediately after applying fluoride varnish reduces the TBS but reaches the optimal value after 30 days of waiting. The use of Recaldent before orthodontic treatment has no adverse effect.

Introduction

Dental caries is one of the most common diseases in modern society, and the prevalence of it reaches about 44% of the world's population\(^1\). Despite considerable efforts by both dentists and other health professionals to reduce the incidence of caries, it has decreased only by 4% in the last thirty years\(^2\). For this reason, there is now an increasing focus on the prevention of tooth decay, which includes not only dietary correction, personal oral hygiene, increase in salivation or the use of prebiotics and probiotics\(^1\), but also the use of substances such as fluoride and calcium phosphoprotein - amorphous calcium phosphate (CPP-ACP), a milk-derived protein which is gaining its popularity these days\(^3\). These substances can be applied professionally or used by the patients themselves\(^4,5\).

This CPP-ACP delivers bioavailable calcium and phosphate ions and acts as a reservoir for these ions\(^6\). Acids release calcium and phosphate ions, which saturate the saliva with ions and then deposit as a calcium phosphate compound on the exposed surface of the tooth\(^7\). CPP-ACP is thought to contribute to deeper ion penetration and thus remineralize not only the superficial enamel layer but also the deeper layers of hard tissue of the tooth, which may also improve the aesthetic appearance\(^8,9\). This complex has antimicrobial properties in part because, by bounding to the dental pellicle, it inhibits the adhesion of *Streptococcus mutants* to the tooth surface that have a solid cariogenic effect\(^10,11\).

It is common knowledge that fluoride therapy reduces enamel demineralization and increases its resistance to organic acids\(^12\). Fluoride has a facilitating effect on the diffusion of calcium and phosphate ions into the demineralized surface. Thus, it can restore the crystalline enamel structure composed of fluorinated hydroxyapatites and fluorapatites, which are more resistant to acids than the primary crystals\(^13\).
It is worth noting that dental and occlusal anomalies are also common today. The prevalence varies from 29.2–93% of the world's population\textsuperscript{14–15}, and the figure is as high as 71% among Europeans\textsuperscript{16}. Due to the high prevalence of such anomalies and the improving economic conditions in both developing and developed countries, people are increasingly focusing on the aesthetics of a smile, leading to an increasing number of patients seeking beautiful smiles through orthodontic treatment\textsuperscript{17}.

Fixed orthodontic appliances - braces - are most often used for dental and occlusal anomalies treatment, for which their adhesion to tooth enamel must reach 5.9–7.8 MPa\textsuperscript{18}. The tensile bond strength of the brackets depends on many factors, such as the structure of the tooth, the etching time and acid used, the type of bracing system, the type of brace, or even previous procedures on the teeth, such as teeth whitening with 35% hydrogen peroxide\textsuperscript{19–22}. There is a significant influence on the structure of tooth enamel, as studies have shown that demineralized or fluorosis-damaged enamel surface significantly reduces the adhesion of braces\textsuperscript{20,23}. The research also indicates that fluoride agents reduce adhesive adherence\textsuperscript{24}, but the data on the effect of remineralizing agents on tensile bond strength are controversial.

The study aimed to evaluate the influence using remineralizing agents on the tensile bond strength.

**Methods**

The present *in vitro* study was performed at the Department of Orthodontics and the Laboratory of Mechanical Engineering Faculty. Bioethical approval was obtained from the Lithuanian University of Health Sciences Bioethical Committee (No: BEC-OF-106) and the methods were carried out in accordance with the relevant guidelines. The informed consent was obtained from all subjects, who participated in the study.

The power analysis with G*Power (Version 3.1.9.2) statistical software was used to determine the sample size. The parameters adopted were as follows: significance level of 5%, power test of 80%, the standard deviation of 3, and smallest effect of interest of 2. The calculation of sample size was based on the following formula:

\[
n = \frac{\sigma^2(Z(\frac{\alpha}{2}) + Z(\beta))^2}{\Delta^2}
\]

where \(n\) – the minimum sample size for each sample;
\(Z(\alpha/2) = 1.96\) and \(Z(\beta) = 0.84\) if \(\alpha = 0.05\) and \(\beta = 0.2\);
\(\sigma\) – standard deviation;
\(\Delta\) - the smallest clinically important difference.
The sample size calculation showed that at least 18 specimens were needed in each group.

Over a period of 1 month, 80 extracted unhealthy and incurable human molars were collected, remnants of blood and soft tissues were removed, and the teeth were washed under a stream of water. Only the molars with intact enamel surface were used for the study: no decay, no restorations, no cracks from the tooth extraction forceps and no hypoplastic areas. Before the study, the teeth were kept in saline, changing it daily.

The teeth were randomly divided into 2 groups (n = 40): the first group (hereinafter referred to as Fluoride Group FG), which used chemically cured fluoride varnish (Bifuoride 10, VOCO GmbH, Cuxhaven, Germany), and the second group (hereinafter referred to as Recaldent Group RG), which used a cream with bioactive calcium and phosphates (GC Tooth Mousse ™, GC Europe, Leuven, Belgium). The buccal surface of each tooth was divided into experimental (mesiobuccal) and control (distobuccal). According to the study protocol, brackets (022 Roth, Discovery, Dentaurum, Ispringen, Germany) were bonded to both surfaces and were submitted to a tension test using a universal testing machine.

Before starting testing tensile bond strength, the buccal surface of each tooth was evaluated with a stereomicroscope (Stemi 2000-CS, Zeiss, Oberkochen, Germany) to assess the enamel cracks. The adhesive remnant index (ARI) was also evaluated after the bracket was pulled.

Remineralizing agents were applied according to the manufacturer's instructions. The proximal buccal surfaces of each group (experimental group) were polished with a rubber cup and non-fluoridated pumice, rinsed with water and dried with a stream of air. The experimental surface of the Recaldent cream group was coated with Recaldent tooth cream (GC Tooth Mousse ™, GC Europe, Leuven, Belgium) using a micro brush and left for 5 minutes according to the manufacturer's instructions, then rinsed with distilled water. The procedure was repeated every 6 hours within the period of 5 days Fluoride varnish (Bifuorid 10, VOCO GmbH, Cuxhaven, Germany) was applied according to the same protocol as Recaldent tooth cream25.

After application, the teeth of both experimental groups were divided into two further subgroups of 20 teeth (n = 20). Braces from one fluorine (FG1) and one Recaldent (RG1) group were bonded and submitted to the tension test 1 day after application (T1), and the teeth of the other two groups (FG30 and RG30) were immersed in saline for 30 days (T2), changing it daily and only after that submitted test19.

The braces of the control group (distobuccal surfaces) were bonded and submitted to a tension test before applying the remineralizing agents to avoid contamination with them.

Before the bonding of the bracket, the buccal surface of each tooth was polished with a rubber cup and non-fluoridated pumice, rinsed with water and air-dried. Following, the prepared enamel areas were etched
with 37% phosphoric acid gel (i-GEL, i-dental Lietuva, Šiauliai, Lithuania) for 30 seconds, then washed and air-dried for 20 seconds until the surface appeared frosted. The etched buccal surface was coated with a thin layer of TruLock bond (Rocky Mountain Orthodontics, Denver, USA) and light-cured for 10 seconds (3M ESPE Epilar, Neuss, Germany, 1200 mW / cm²).

Directly afterwards, identical premolar metal braces (022 Roth, Discovery, Dentaurum, Ispringen, Germany) were bonded using light-cured TruLock adhesive resin (Rocky Mountain Orthodontics, Denver, USA). Each bracket was positioned 1 mm gingivally to the buccal cusp tip and pressed against the buccal tooth surface with an adapter using a force of 100 g (9.8 N), all done by the same person to ensure the standard thickness of the adhesive. A dental probe was used to remove residual adhesive around the bracket. Bracket adhesive was light-cured for 20 seconds (3M ESPE Epilar, Neuss, Germany, 1200 mW / cm²)²⁶,²⁷. All samples were kept in saline for 24 hours after bonding to achieve complete resin polymerization.

The tensile bond strength (TBS) was measured in the Department of Mechanical Engineering at the Kaunas University of Technology. The loops were bent from the orthodontic archwire and fixed to the brackets with ligatures (Fig. 1). Then they were adjusted to the universal mechanical testing machine (H24KT, Tinius Olsen, England). The testing machine was used at a crosshead speed of 5 mm/min until the bracket was debonded from the tooth. The highest debonding forces (N) of the brackets were recorded automatically by a digital software measurement system. The system consisted of a force sensor (SS50, Wagner Instruments, USA, 250 N x 0.1 N) and a controller with a display (BGI, Wagner Instruments, USA). TBS was calculated using the force's value and the base of the bracket area value (1 MPa = 1 N/mm²)

After debonding the brackets, each bracket was analyzed with a stereomicroscope (Stemi 2000-CS, Zeiss, Oberkochen, Germany), and images were taken with a digital microscope camera (AxioCam, MRC 5, Zeiss, Oberkochen, Germany), which were superimposed on a 100 x 100 cell scale²⁰. Adhesive residues were evaluated using the ARI index. The ARI values were divided into 6 groups according to the percentage of adhesive remnant on the bracket: 1 - when there is no composite on the bracket base, 2 - less than 20% of the composite remains on the bracket base, 3 - composite residue covers 20–40% of the bracket base, 4 - composite residue covers 41–60% of the bracket base, 5 - composite residues cover 61–80% of the bracket base; 6 - composite residues cover 81% or more of the bracket base²⁰,²⁶.

Statistical analysis was performed using IBM SPSS 28.0.1.1. Tensile bond strength (TBS) data were analyzed by one-way ANOVA and Tukey posthoc methods of descriptive statistics. ARI data were analyzed by the Chi-Square method. The difference in results between the variables was considered statistically significant if p < 0.05.

Results

Tensile bond strength (TBS) analysis
The data obtained were normally distributed according to the Shapiro-Wilk test, so one-way ANOVA and Tukey post-hoc tests were used. Descriptive statistics, including mean, standard deviation, maximum and minimum adhesion force values for each group of brackets, are shown in Table 1. The analysis showed that a statistically significant (p <0.001) difference in the means TBS was found between the fluoride group FG1 (5.47 MPa; SD = 0.91) when the bracket was removed the day after application, and the control (7.10 MPa; SD = 0.81) and other experimental groups.

When the bracket was removed 30 days after the application of fluoride varnish (6.66 MPa; SD = 0.82), the tensile bond strength was lower than in the control group, but no statistically significant difference was found (p = 0.215). No significant difference was found between Recaldent tooth cream application and different debonding times compared to each other and the control group (p> 0.05) (Figure 2.).

ARI analysis

Table 2. shows the adhesive remnant index values. The Chi-Square test showed a statistically significantly higher amount of adhesive residue on the bracket of the FG1 group (p <0.001) compared to the control group, where more resin remained on the tooth than on the debonding. No statistically significant difference in ARI was found between the other experimental groups and the control group.

Discussion

The development of caries before and during orthodontic treatment is a significant issue. Prevention of caries and orthodontic treatment are inevitable due to the high prevalence of caries and occlusal anomalies, which rank first and third in all oral diseases, respectively16. However, the influence on TBS of preventive measures of caries that include remineralizing agents is controversial.

In this study, the mean TBS for all groups, except for the fluoride varnish group, in which the braces were TBS, was measured the day after application (5.47 MPa; SD = 0.91), fell within the Reynolds recommended range of optimal bracket adhesion equal to 5.9–7.8 MPa18.

Based on the results obtained and studies performed by other researchers, it can be assumed that the prophylactic use of fluoride leads to lower bracket retention. This is consistent with studies by Leóldido et al., Daneshkazemi et al., Cossellu et al., in which the TBS ranged from 6.62 MPa to 9.97 MPa in the fluoride group and from 12.82 MPa to 17.38 MPa in the control group19,23,25. This may be since fluoride ions replace calcium ions in the surface layer of the enamel to form fluorapatites, which are more resistant to environmental influences, as well as phosphoric acid, which is used to etch the enamel. As a result, the depth of penetration of the bonding system into the enamel may decrease25. However, such a potential negative effect of fluoride on tensile bond strength should not outweigh its positive effects in prophylaxis.

When evaluating the effect of Recaldent tooth cream, the TBS was lower immediately after application of the cream (6.80 MPa; SD = 0.86) when compared to the control group (7.10 MPa; SD = 0.81) but this
difference was not statistically significant ($p > 0.05$). Cehreli and co-authors as well as Dunne W.J. found that application of CPP-ACP prior to bonding reduced retention\textsuperscript{27,28}. Naseh et al.\textsuperscript{29} and Daneshkazemi et al.\textsuperscript{25} investigated that the use of CPP-ACP cream before fixation of the braces did increase the TBS compared to the control group, although not statistically significant. On the other hand, in studies by Xiaojun et al.\textsuperscript{30} and Kecik et al.\textsuperscript{31}, this increase was statistically significant. Such different data are possible due to the different method of application of the substances.

In this study, the application method of remineralizing agents was used as in the study by Daneshkazemi and co-authors\textsuperscript{24}. Both Recaldent cream and fluoride varnish were applied to the tooth surface for 5 minutes, followed by rinsing with repeated water every 6 hours 5 days. The chosen methodology made it possible to simulate the \textit{in vivo} study as much as possible but at the same time to shorten the study time.

However, it is essential to note that in the study, the teeth were kept in artificial saliva. According to Naseh and co-authors\textsuperscript{29}, artificial saliva creates the most similar environment to oral conditions. However, in this study, the use of saline was chosen to determine the effect of remineralizing agents alone more objectively on tensile bond strength, ruling out the potential impact of salivary minerals.

Regarding ARI, this study found that a statistically significant amount of resin remained on the bracket in the fluoride varnish group when the brackets were bonded the day after the last application of the fluoride varnish, although in a study by Cossellu and co-authors\textsuperscript{19} no statistically significant difference was found between ARI values. No significant differences in ARI values between control and experimental groups were found in other studies as well\textsuperscript{25,29}. However, such results may have been affected by slightly different ARI assessment methodologies and scores values\textsuperscript{19,21,25,29,31}.

Finally, this study showed that remineralizing agents used to prevent caries have a few adverse effects on bracket adherence. That is especially pronounced in the first days after fluoride varnish applications, and the differences become insignificant after 30 days. GC Tooth Mousse Recaldent applications, meanwhile, have a significantly smaller impact. However, for even more accurate results, it would be appropriate to investigate an even larger sample in the future.

\textbf{Limitations Of The Study}

This study was \textit{in vitro} study, thus it was impossible to repeat the tension test with the same teeth.

\textbf{Conclusion}

The tensile bond strength was significantly lower than that with the bracket bonded one day after the fluoride varnish application on the tooth surface. After debonding, more resin remained on the braces than on the tooth surface. However, the adhesion of the brackets reached the optimal value after 30 days of fluoride varnish application.
Application of GC Tooth Mousse Recaldent cream on the tooth surface had no negative effect on TBS.

**Declarations**

**DATA AVAILABILITY**

A data can be available under reasonable request. If someone wants to request the data from this study a corresponding author Milda Domantaite should be contacted; E-mail milda.domantaite@stud.lsmu.lt

**ACKNOWLEDGEMENTS**

We would like to thank Mechanical Engineering faculty Laboratory personae in Kaunas University of Technology for the opportunity to use their equipment during the investigation.

**CONTRIBUTIONS**

M.D. was responsible for the study design, preparation of the materials, analyzed the materials and results, wrote the main manuscript text and prepared it for submission. G.T. was responsible for the study design, for the preparation of the material, analyzed material and results, reviewed the manuscript.

**ADDITIONAL INFORMATION**

No.

**COMPETING INTEREST STATEMENT**

The authors do not have any funding, employment, personal financial or non-financial interests with values that may be affected by the publication.

**References**


Tables

Table 1. Descriptive Statistics of the Groups and Comparison of TBS Values

n - sample size; SD – standard deviation; Min - the smallest value; Max – the biggest value; FG1 – fluoride varnish group a day after application; FG30 – fluoride varnish group 30 after application; RG1 – Recaldent tooth mousse group a day after application, RG30 – Recaldent tooth mousse group 30 days after application.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>80</td>
<td>7.10</td>
<td>0.81</td>
<td>5.74</td>
<td>9.17</td>
</tr>
<tr>
<td>FG1</td>
<td>20</td>
<td>5.47</td>
<td>0.91</td>
<td>3.14</td>
<td>7.03</td>
</tr>
<tr>
<td>RG1</td>
<td>20</td>
<td>6.80</td>
<td>0.86</td>
<td>5.19</td>
<td>8.89</td>
</tr>
<tr>
<td>FG30</td>
<td>20</td>
<td>6.66</td>
<td>0.82</td>
<td>5.53</td>
<td>8.32</td>
</tr>
<tr>
<td>RG30</td>
<td>20</td>
<td>7.05</td>
<td>0.69</td>
<td>5.87</td>
<td>8.10</td>
</tr>
</tbody>
</table>

Table 2. The distribution and frequency of the adhesive remnant index (ARI) between control and experimental groups. n – sample size; FG1 – fluoride varnish group a day after application; FG30 – fluoride varnish group 30 after application; RG1 – Recaldent tooth mousse group a day after application, RG30 – Recaldent tooth mousse group 30 days after application; *p<0.05 (significant)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>ARI</th>
<th>p*Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Control</td>
<td>80</td>
<td>16 (20%)</td>
<td>20 (25%)</td>
</tr>
<tr>
<td>FG1</td>
<td>20</td>
<td>0 (0%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>RG1</td>
<td>20</td>
<td>2 (10%)</td>
<td>4 (20%)</td>
</tr>
<tr>
<td>FG30</td>
<td>20</td>
<td>3 (15%)</td>
<td>4 (20%)</td>
</tr>
<tr>
<td>RG30</td>
<td>20</td>
<td>4 (20%)</td>
<td>5 (25%)</td>
</tr>
</tbody>
</table>

Figures
Figure 1

Tooth fixed in universal testing machine

Figure 2

Average TBS of brackets compared by the different agents used. FG1 – fluoride varnish group a day after application; FG30 – fluoride varnish group 30 after application; RG1 – Recaldent tooth mousse group a day after application, RG30 – Recaldent tooth mousse group 30 days after application.