

Evaluation of metallic brackets adhesion after the use of bleaching gels with and without amorphous calcium phosphate (ACP): *In vitro* study

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Objective: To evaluate *in vitro* the effects of tooth whitening using gel with Amorphous Calcium Phosphate (ACP) on the bond strength of metal brackets. **Methods:** Thirty-six bovine incisors were sectioned at the crown-root interface, and the crowns were then placed in PVC cylinders. The specimens were divided into 3 groups (n = 12) according to whitening treatment and type of gel used, as follows: G1 (control) = no whitening; G2 = whitening with gel not containing ACP (Whiteness Perfect - FGM), G3 = whitening with gel containing ACP (Nite White ACP - Discus Dental). Groups G2 and G3 were subjected to 14 cycles of whitening followed by an interval of 15 days before the bonding of metal brackets. Shear bond strength testing was performed on a Kratos universal test machine at a speed of 0.5 mm/min. After the mechanical test, the specimens were assessed to determine the adhesive remnant index (ARI). The results were subjected to ANOVA, Tukey's test and Kruskal-Wallis test (5%). **Results:** Significant differences were noted between the groups. Control group (G1 = 11.10 MPa) showed a statistically higher shear bond strength than the groups that underwent whitening (G2 = 5.40 MPa, G3 = 3.73 MPa), which did not differ from each other. There were no significant differences between the groups in terms of ARI. **Conclusion:** Tooth whitening reduces the bond strength of metal brackets, whereas the presence of ACP in the whitening gel has no bearing on the results.

Keywords: Tooth whitening. Dental bonding. Shear bond strength. Orthodontics. Tooth enamel.

Objetivo: avaliar, *in vitro*, a influência do clareamento dentário com gel contendo fosfato de cálcio amorfo (ACP) na resistência da união adesiva de braquetes metálicos. **Métodos:** trinta e seis dentes incisivos bovinos foram seccionados no limite coronorradicular e tiveram suas coroas incluídas em cilindros de PVC. Os corpos de prova foram divididos em três grupos (n = 12), de acordo com a realização do tratamento clareador e tipo de gel utilizado, sendo: G1 (controle) – sem clareamento; G2 – clareamento com gel sem ACP (Whiteness Perfect, FGM); G3 – clareamento com gel contendo ACP (Nite White ACP, Discus Dental). Os grupos G2 e G3 foram submetidos a 14 ciclos de clareamento, seguidos de intervalo de espera de 15 dias para a fixação adesiva dos braquetes metálicos. O ensaio mecânico de cisalhamento foi realizado em máquina universal Kratos, com velocidade de 0,5mm/min. Após o teste mecânico, os corpos de prova foram avaliados quanto ao índice de remanescente adesivo (ARI). Os resultados foram submetidos à ANOVA, ao teste de Tukey e ao de Kruskal-Wallis ($\alpha = 5\%$). **Resultados:** diferenças significativas foram observadas entre os grupos testados. O grupo controle G1 (11,1MPa) mostrou uma resistência ao cisalhamento estatisticamente superior aos grupos submetidos ao clareamento (G2 = 5,40MPa; G3 = 3,73MPa), os quais não diferiram entre si. Não se observou diferença significativa para o ARI entre os grupos estudados. **Conclusão:** o clareamento dentário reduz a resistência da união adesiva de braquetes metálicos, enquanto a presença de ACP no gel clareador não influencia os resultados encontrados.

Palavras-chave: Clareamento de dente. Colagem dentária. Descolagem dentária. Ortodontia. Esmalte dentário.

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INTRODUCTION

Human beings' motivation towards body esthetics and beauty has been increasingly extended to the smile.²⁹ Dental esthetics is now a primary factor in seeking dental treatment, thus rendering teeth whitening a very sought procedure. Therefore, today this procedure is usually performed prior to different treatments in dentistry, such as tooth alignment with orthodontic appliances.

To be successful, orthodontic treatment with fixed appliances depends, among other factors, on proper bonding of brackets and a lasting retention of these attachments to the teeth. The need to rebond orthodontic attachments can severely hinder treatment progress, thereby increasing biological and financial costs.²² These attachments are placed on the tooth enamel and are subject to a wide range of intraoral forces, which is often entirely delivered to the bonding adhesive layer and the adhesive/enamel interface.⁶ Thus, any treatment of the tooth surface using chemicals – such as whitening agents – could potentially affect bond strength.²²

Nowadays, teeth whitening is a widespread cosmetic procedure in society, with a number of whitening products available in the market. Among the existing techniques, at-home whitening, which involves low concentrations, has evolved into a very popular technique given its effectiveness and convenience.⁷ However, even with the use of low concentrations, several studies report changes in tooth structure in the whitened areas.^{18,31} There are differences in the degree of adverse effects caused by whitening vital teeth.³⁰

Although it has been found that whitening teeth with carbamide peroxide at 10% does not interfere with bond strength to the enamel when performed prior to the bonding of brackets,² there have been reports¹⁸ of interferences with the mechanical bonding of orthodontic appliances to enamel previously subjected to the whitening procedure. Remnants from the whitening material possibly interfere with the composite by changing or preventing the formation of tags, thus impairing mechanical bond strength.

Some of the noteworthy changes occur in the mineral content of the whitened teeth, which can generate: Increased porosity and permeability of the enamel, which reduces its microhardness, undermines

bond strength after whitening, and an increase in dentin hypersensitivity during and after treatment.⁵ In an attempt to avoid or minimize the undesirable effects that may occur in the whitened tooth structure dental products have been launched on the market with some changes in their composition.

Recently, whitening gels and amorphous calcium phosphate (ACP), or just calcium, have been added to the composition. Manufacturers claim that these substances can supply minerals to the whitened tooth structure and thereby prevent the emergence of porosities and erosions. Additionally, they contribute to reducing trans- and postoperative sensitivity by decreasing enamel permeability, inhibiting neural activation and/or obliterating exposed and open dentinal tubules.¹¹ However, few studies have been published on the behavior of these whitening gels as well as how their use can influence the bond strength of orthodontic appliances. The present study therefore aimed to use these new products as a means to investigate the potential effects of employing them prior to bracket bonding.

OBJECTIVE

To evaluate, *in vitro*, the bond strength of orthodontic brackets after tooth whitening with and without ACP through mechanical shear bond tests. The adhesive remnant index (ARI) of orthodontic brackets after the use of different dental whitening agents was also examined.

MATERIAL AND METHODS

This study was approved by the Ethics Committee for Animal Research (CEPAN) of the Pará State University (UEPA) under file n° 067-2009.

The study included 36 recently extracted bovine teeth, all permanent mandibular incisors, supplied by a slaughterhouse in the city of Belem, Pará State (PA). The selection criteria required that each tooth enamel be intact, with no cracks and no prior use of chemical agents. Teeth with anatomical irregularities in their labial surfaces were also excluded from the study. The specimens were stored in aqueous solution, and the water was changed every 5 days at room temperature.

After the extractions, followed by removal of periodontal tissues and rinsing, the teeth were stored in distilled water. Thereafter, the root portion was removed with a stainless steel disc (Starret - Germany)

at low speed, the pulp was removed with endodontic curettes (Ice - SP). Subsequently the crowns were attached to 25 x 20 mm PVC cylinders with self-curing acrylic resin (JET, São Paulo, SP), so that the most prominent portion and central labial surface of the teeth was exposed perpendicularly to the cylinder. This position was obtained with the aid of a square by determining a 90° angle between the labial surface of the crown and the cylinder base.

Prophylaxis was performed on the labial surface of the teeth with a rubber cup and pumice (fine-grained and without fluoride - JET-São Paulo/SP) for 10s and then each specimen was rinsed with water/air sprays for an equal time length.

Groups

The specimens were randomly divided into three groups (n = 12) according to whether or not they had been whitened, and the type of whitening gel (Table 1). The gels were applied as recommended by the manufacturers on the labial surface of the enamel in a layer about 0.5 mm thick, which corresponded to one cycle. Upon completion of each gel application cycle the specimens were washed with air/water jets for 30 seconds, and thereafter immersed in distilled water renewed weekly and stored at 34° C room temperature on average. Fourteen cycles were carried out spanning a 15-day time interval since the end of the whitening treatment. Only then were the brackets bonded to the teeth.

Standard Edgewise metal brackets with slots 0.022 x 0.028-in (Abzil, 3M/Unitek, São José do Rio Preto/SP, Brazil) were bonded to the maxillary central incisors. The size of the bracket base, as informed by the manufacturer, was 14.35 mm.² The base featured

metal mesh type mechanical retention. Transbond XT adhesive system (3M Unitek, Monrovia, CA, USA) was used for bonding the brackets. The brackets were bonded to the tooth surface with the slot parallel to the base of the cylinder, following the manufacturer's protocol.

To perform the shear bond strength test of the specimens a Kratos TRCV59DUSB universal mechanical testing machine (Jundiaí, SP, Brazil) was utilized at a speed of 0.5 mm/min (ISO 11405:2003)¹⁴ with a chisel tip. Shear bond strength results were obtained in kgf, converted to N, and divided by the bracket base area (14.35 mm²), yielding the results in MPa.

After conducting the test, the labial surface of each specimen was evaluated by stereomicroscopy (Opton, Germany) with 8x magnification to measure Adhesive Remnant Index (ARI), as recommended by Årtun and Bergland,¹ where 0 = no composite remnant adhered to the enamel, 1 = less than half of composite adhered to the enamel, 2 = more than half of composite adhered to enamel, 3 = all composite adhered to the enamel.

Statistical analysis

All data were analyzed for normality by the Shapiro-Wilk test was used for normality analysis of all data. Data were considered normal after excluding an outlier (Group 2). If this specimen had been included the data would have been considered abnormal.

Shear bond strength test results were subjected to analysis of variance (ANOVA) at 5% significance level, and subsequently Tukey's test to compare the control group with the other treatments, and also between the experimental groups (G2 and G3). Kruskal-Wallis test at 5% was used in evaluating ARI scores.

Table 1 - Experimental groups, product/manufacturer and basic composition of whitening gels.

EXPERIMENTAL GROUPS	PRODUCT/MANUFACTURER	BASIC COMPOSITION
GROUP 1		
G1 (n = 12): Standardized bracket bonding, and shear bond test without prior whitening - control group.	-----	-----
GROUP 2		
G2 (n = 12): 14 cycles of at-home whitening without ACP - 15-day time interval immersed in distilled water. Bracket bonding and shear bond test.	Whiteness Perfect / FGM Lot 181209	Carbamide peroxide at 16% + Potassium Nitrate + Fluoride
GROUP 3		
G3 (n = 12): 14 cycles of at-home whitening with ACP - 15-day interval immersed in distilled water. Bracket bonding and shear bond test.	NiteWhite ACP / Discus Dental Lot 08315151	Carbamide peroxide 16% + Potassium nitrate + Calcium + Phosphate

RESULTS

ANOVA analysis of variance results with p values are depicted in Table 2.

Differences in bond strength between groups are displayed in Figure 1, which shows a significant difference between Group 1 – control (not whitened), and the groups after whitening (Group 2 – conventional whitening product, and Group 3 – whitening product containing ACP). No significant differences were found between the whitened groups.

The value of the Kruskal-Wallis statistical test for ARI was $p = 0.0509$, indicating a statistically insignificant difference. Figure 2 shows ARI in both groups.

DISCUSSION

A number of studies have evaluated the bond strength of orthodontic brackets bonded to different surfaces.^{3,20,27} In this context, preference has been given to central incisor brackets as they feature a flatter base surface, which adapts more easily to the surfaces being tested. These surfaces are normally flat since specimens are seldom fabricated with crown contours, which explains the brackets used in this experiment.

Table 2 - P values of the statistical test between experimental groups.

Groups	p value
Groups 1 and 2	< 0.05
Groups 1 and 3	< 0.01
Groups 2 and 3	n.s.

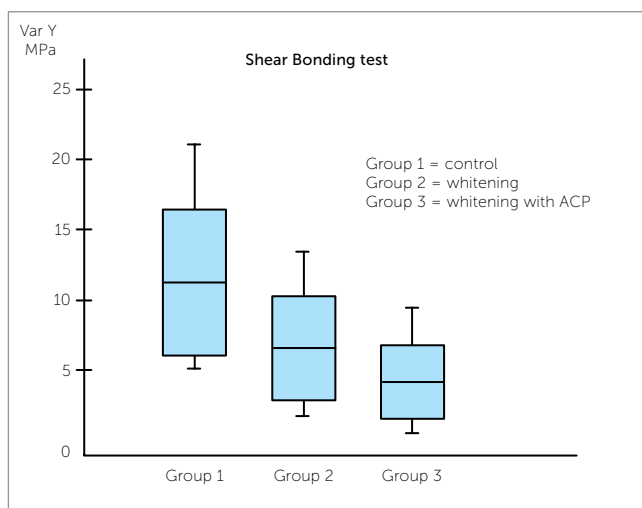


Figure 1 - Shear bond strength values, means and standard deviations of groups 1, 2 and 3.

Nevertheless, it is noteworthy that *in vitro* tests exhibit numerous differences compared with *in vivo* tests. The key difference lies in the fact that the forces which occur during mastication are compressive in nature and pose a greater risk of damage to enamel than forces applied to the bracket/adhesive during shear bond tests.¹³ These peculiarities of laboratory tests should be emphasized as they improve variable control. Conversely, clinical studies do not allow these variables to be controlled, which warrants further studies on this topic.

In actuality there is no such thing as a pure shear force *in vivo*, given that the different components combine to influence the bond. Moreover, *in vitro* results undergo significant effects, as shown by Swift Jr., Perdigão,²⁹ Bishara and Sulieman.⁴ Despite the above, this investigation followed the methodology adopted by the ISO/TS11405 standard.

As regards the type of substrate used, bovine teeth have long been considered a good alternative since not only are they more readily available but their enamel structure is similar to that of human teeth. Assessments made by comparative studies involving different substrates show that the bond strength of bovine enamel is quite acceptable, although their bond strength may be lower compared to human teeth.^{9,21}

Another noteworthy aspect concerns the storage medium adopted in the present study (distilled water). In bond strength tests of whitened substrates the storage medium used for the specimens plays a role as relevant as it is controversial. Artificial saliva, which

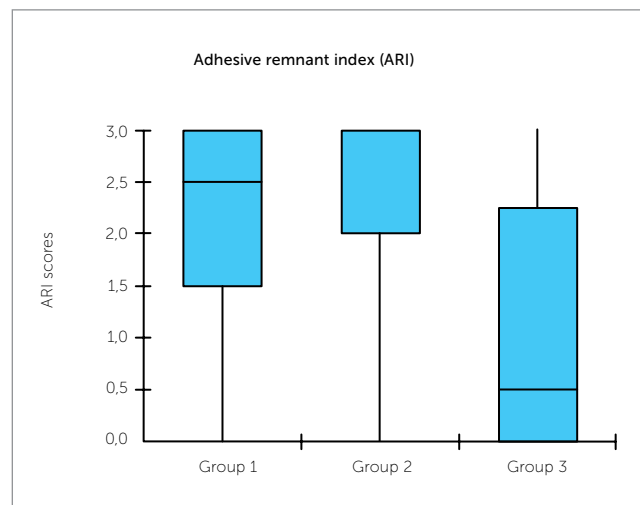


Figure 2 - Adhesive remnant index (ARI), median and quartile in groups 1, 2 and 3.

has been employed in different studies,^{8,10,16,17,28} is primarily aimed at making laboratory tests resemble as closely as possible the clinical conditions actually experienced in routine practice.

As to the mechanical test, it is a known fact that orthodontic brackets require a bond strength capable of withstanding masticatory forces and activation of the mechanics utilized.²¹ The minimum acceptable bond strength for routine orthodontic procedures ranges from 6 to 8 Mpa.²¹ The results showed unacceptable mean bond strength values for whitened teeth.

Thus, artificial saliva has often been blamed for the lack of differences in bond strength after whitening, according to published studies.^{15,19} This finding could be attributed to the remineralizing effect of saliva cited by Souza,²⁸ who argued that enamel samples treated with 10% carbamide peroxide and stored in artificial saliva display smaller spaces in between the hydroxyapatite crystals. However, other studies^{29,30} claim that this potential remineralizing effect of saliva has not yet been properly explained.

Therefore, in order to avert a possible potentiating (remineralizing), or deleterious effect by artificial saliva, which could interfere with the analysis of the results, a storage medium, i.e., distilled water, was chosen as it exerts little or no effect on bond strength.

Residues derived from the degradation of peroxide or oxygen leads to a lower amount of shorter resinous tags compared to teeth not subjected to whitening,^{7,18} resulting in lower bond strength as hydrogen peroxide negatively affects the curing of adhesive systems.^{12,14,16,23,30}

Therefore, teeth whitening can change the mineral structure of tooth enamel and, hence, affect the bond between this substrate and adhesive systems.^{24,25} It is thus necessary to wait for a post-whitening period long enough for the enamel's mineral structure to be restored, and for the residual oxygen of the whitening agent to be completely removed. Although the literature shows significant variation in the length of the post-whitening period recommended before bonding brackets (24h to 4 weeks), Cavalli⁸ showed that a minimum of two weeks would be required for the structure to recover its adhesive properties. The results led the authors to believe that 15 days were not sufficient to restore the enamel, suggesting therefore

that a longer time interval should be allowed to elapse prior to bonding any orthodontic appliances.

Furthermore, removal of the remaining resin from the tooth surface does not pose a challenge since removal of adhesive remnants from tooth surfaces after removal of the fixed orthodontic appliance is a routine procedure. Thus, the choice of bonding materials depends on a careful assessment of their clinical properties. This finding concerning the adhesive remnant index (ARI) is of great interest to the orthodontist, who can thus choose materials that respond clinically by presenting a greater amount of adhesive remnants on the tooth surface after removal of the brackets. This should ensure greater safety, preventing enamel fractures and preserving tooth integrity.

Although the use of hydrogen peroxide at 35% significantly reduces the amount of resin on the tooth surface after debonding,³¹ this study did not reveal any differences in terms of ARI in both whitened and non-whitened teeth, with and without ACP.

Proper orthodontic treatment requires scientific knowledge and special technical skills. It is also paramount that orthodontists be instructed about the wide array of materials of different types and manufacturers currently available for clinical use. There are various products of different origins, both domestic and imported, manufactured specifically for direct bonding of orthodontic attachments to enamel. It is therefore extremely important that these results be applied in clinical practice in order to optimize professional orthodontic treatment, thus avoiding frequent bond failures due to poor bond strength between brackets and tooth enamel.

CONCLUSION

Significant differences were found in the bond strength of metal brackets between whitened and non-whitened teeth. There was a considerable reduction in bond strength in the groups that were subjected to tooth surface whitening. Both whitened groups (2 and 3) failed to achieve a clinically efficient bond strength, especially group 3 (whitened with ACP), underscoring the need to restore the tooth surface and remove all chemical whitening agents prior to bonding the brackets. As regards ARI, there was no statistically significant difference between the 3 groups tested.

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