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# INFLUENCE OF MODIFICATION OF ATTACHMENT BASE AND SALIVA CONTAMINATION ON THE BOND STRENGTH OF ORTHODONTIC TUBES BONDED TO HUMAN ENAMEL

## INFLUÊNCIA DA MODIFICAÇÃO DA BASE DE COLAGEM E DA CONTAMINAÇÃO SALIVAR NA RESISTÊNCIA DE UNIÃO DE TUBOS ORTODÔNTICOS COLADOS AO ESMALTE HUMANO

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**ABSTRACT**

The objective of this *in vitro* study was to assess and compare the shear bond strength of conventional and modified orthodontic tubes bonded to the surface of dry and saliva-contaminated enamel. The sample consisted of 40 human teeth, which were randomly divided into four groups according to attachment base and presence or absence of saliva contamination as follows: Group CB, conventional orthodontic tubes without salivary contamination; Group CB-S, conventional orthodontic tubes with salivary contamination; Groups BM, orthodontic tubes modified by welding a metal mesh to their base without salivary contamination; and Group BM-S, modified orthodontic tubes with salivary contamination. Shear bond strength test was performed in a universal testing machine and analysis of the adhesive remnant index (ARI) by optical microscopy. Two-way ANOVA was used, followed by Tukey's test at a statistical significance level of 5%. The ARI results were analysed descriptively. There was statistically significant difference between the groups regarding the shear bond strength values, with conventional tubes presenting significantly higher values ($P < 0.05$). In addition, the presence of salivary contamination interfered negatively with the behaviour of conventional tubes only ($P < 0.05$). Shear bond strength was not improved by increasing the area of the orthodontic tubes. Moreover, salivary contamination influenced negatively the SBS values, but only when conventional tubes were used.
**Keywords:** Dental bonding. Malocclusion. Orthodontics. Shear bond strength.

**RESUMO**

O objetivo deste estudo *in vitro* foi avaliar e comparar a resistência de união ao cisalhamento de tubos ortodônticos convencionais e modificados, colados às superfícies de esmalte secas e contaminadas com saliva. A amostra foi composta por 40 molares humanos, que foram divididos aleatoriamente em quatro grupos conforme a base de colagem e presença ou não de contaminação salivar: Grupo BC, tubos ortodônticos com base convencional e sem contaminação salivar; Grupo BC-S, tubos ortodônticos com base convencional, mas com contaminação salivar; Grupo BM, tubos ortodônticos modificados com a inclusão de malha metálica soldada à base e sem contaminação salivar; e Grupo BM-S, tubos ortodônticos modificados, mas com contaminação salivar. O teste de resistência de união ao cisalhamento (Ru) foi realizado em máquina universal de ensaios mecânicos e a análise do índice de remanescente adesivo (IRA) por meio de microscopia ótica. Para análise dos dados de Ru, foi utilizada análise de variância a dois fatores (ANOVA), seguido do teste de Tukey, ao nível de significância estatística de 5%. Os resultados do IRA foram analisados descritivamente. Houve diferença estatisticamente significante entre os grupos quanto à Ru ($p<0,05$), sendo que os tubos convencionais apresentaram valores significantemente maiores. Além disso, a presença de contaminação salivar interferiu negativamente apenas no comportamento dos tubos convencionais ($p<0,05$). Os valores de resistência de união ao cisalhamento não aumentaram em função do aumento da área dos tubos ortodônticos. Com relação à contaminação salivar, esta influenciou negativamente os valores de Ru apenas quando foram utilizados tubos convencionais.

**Palavras-chave:** Colagem dentária. Má-oclusão. Ortodontia. Resistência ao cisalhamento.


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## INTRODUCTION

Orthodontic bands have been used for years and their mechanical advantages in terms of strength and force gradients are widely known (BANKS; MACFARLANE, 2007). According to Gange (2015), however, orthodontic bands may cause undesirable periodontal problems when placed on interproximal facets, such as gingival trauma and pain on placement, including a higher risk of bacteremia (ERVERDI *et al*., 2001). This scenario has encouraged the replacement of cemented bands with directly bonded orthodontic tubes (ALEXANDER, 1991; BOYD; BAUMRIND, 1992; SCOUGALL-VILCHIS; OHASHI; YAMAMOTO, 2009; MELO *et al.*, 2012). Some advantages cited by Murray, Millett and Cronin (2012) are clearly evidenced, such as efficient operative time (TALPUR *et al.*, 2012), easy detection of carious lesions due to better visibility of enamel (ZACHRISSON, 1976), lower number of visits and less risk of contamination (BOYD; BAUMRIND, 1992; BANKS; MACFARLANE, 2007), more comfort for the patient and less risk of demineralisation (BANKS; MACFARLANE, 2007), easy examination and need for less space in the arch for orthodontic treatment and possible restorative interventions (ALEXANDER, 1991; BOYD; BAUMRIND, 1992; MELO *et al.*, 2012).

For achieving an effective orthodontic bonding, the accessory must support enough force so that mechanical failures can be prevented, which can compromise its function. Reynolds (1975) suggested that a force ranging from 5.9N to 7.8N is enough for orthodontic brackets resist masticatory efforts. Although this value is empirically determined, it is clinically accepted as a sufficient force for orthodontic brackets resist the shearing forces of mastication (SCOUGALL-VILCHIS; OHASHI; YAMAMOTO, 2009).

Several factors have influence on the bond strength of brackets to the enamel, such as the type of adhesive, as cited by Millett *et al.* (2001), Evans *et al.* (2009) and Brauchli *et al.* (2010), and contamination with saliva and/or blood during the bonding process. Presence of contaminants is common in the daily practice of orthodontists. Therefore, it is important to determine the degree of influence of these factors on the shear bond strength (CACCIAFESTA *et al.*, 2003; KHANEHMASJEDI *et al.*, 2017; SHAIK *et al.*, 2018).

The shape of the bracket base is another factor which may be considered important for the bond strength (REYNOLDS, 1975; ØGAARD; FJELD, 2010). However, some studies have shown that the dimensions of the tube's base for attachment may not be a determinant factor to improve the bond strength. These studies relate such improvement mainly to enamel surface treatment and type of mesh of pre-fabricated tubes rather than to the size of their base (REYNOLDS, 1975; LOPEZ, 1980; MACCOLL *et al.*, 1998). In addition, there is indication that the air entrapped in the retention mesh can cause loss of adhesion and thus interfere with the bond strength, since the presence of oxygen can inhibit polymerisation (FINGER; JORGENSEN, 1976; MAIJER; SMITH, 1981).

Contrary to these studies, which used original pieces (i. e. non-modified) at the surface of the bases, the proposition of our work was to assess whether the bonding strength can be improved by modifying the attachment base of orthodontic tubes by means of welding a metal mesh to pre-fabricated ones. According to Maijer e Smith (1981), it is presupposed that such extension can increase the bonding area and impede air trapping as the mesh is open, thus decreasing the effect of salivary contamination and making bonding more effective. If the shear bond strength is improved, in association with the mentioned above advantages of using bonded tubes, then there would be additional reasons for not using orthodontic bands.

In this context, the objective of the present study was to assess the shear bond strength of conventional and modified orthodontic tubes bonded to the surface of dry and saliva-contaminated enamel for assessment of failure pattern.

## MATERIAL AND METHODS

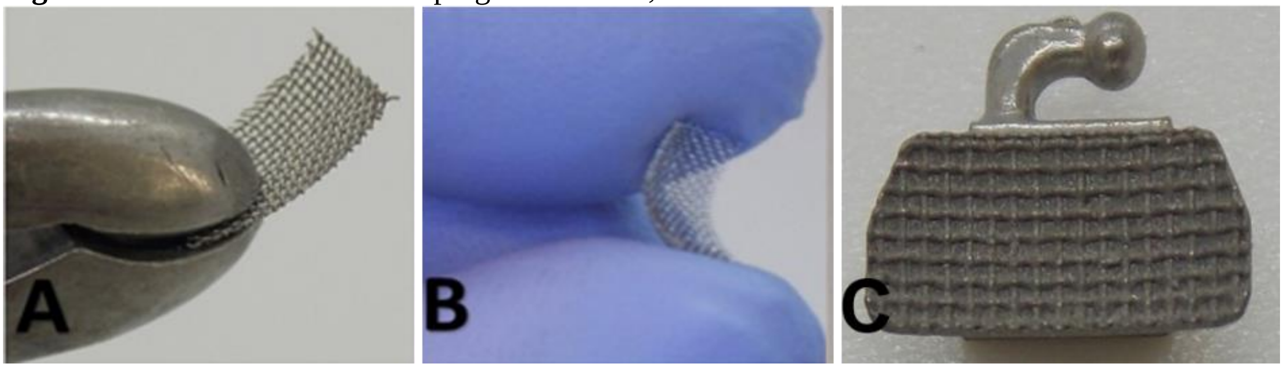
This study was approved by the local research ethics committee according to protocol number 3356832. Sampling calculation was based on significance levels of alpha of 5% and beta of 20% to obtain a power of 80% so that a mean value of shear bond strength of 6 MPa and standard deviation of 3 MPa were achieved for a total of nine specimens *per* group (TALPUR *et al.*, 2012). Ten specimens were used in the present study.

In this way, the sample consisted of 40 newly-extracted human lower molars, all with sound crowns and presenting no demineralisation, cracks or fractures. Anatomically changed teeth were excluded as their buccal faces could not be used. The teeth were cleaned with periodontal curettes (Duflex SS White, São Cristovão, RJ, Brazil) and their buccal faces were submitted to prophylaxis with rubber cups (Microdont, São Paulo, SP, Brazil) and polishing paste (SS White, Petropolis, RJ, Brazil) for 10 seconds before being washed and dried for 10 seconds. The rubber cups were replaced every five procedures (KNOLL; GWINNETT; WOLFF, 1986; CACCIAFESTA *et al.*, 2003; CAMPOY; VICENTE; BRAVO, 2005).

Next, the teeth were randomly divided into four groups (n = 10), according to attachment base and presence or absence of salivary contamination as follows: in Group CB, conventional orthodontic tubes were used without salivary contamination; in Group CB-S, conventional orthodontic tubes were used with salivary contamination; in Groups BM, orthodontic tubes modified by the inclusion of a welded metal mesh to their base were used without salivary contamination; and in Group BM-S, modified orthodontic tubes were used with salivary contamination. The accessories used were orthodontic double tubes (Morelli®, Sorocaba, Brazil).

The orthodontic tubes were modified by welding a stainless steel mesh (#80 orthodontic mesh base, Morelli®, Sorocaba, SP, Brazil) to their base and then sectioned with a cutting stylus and golden scissors in order to extend the base by 1.0 mm in the cervical, occlusal, mesial and distal directions (Figure 1). Band-forming pliers were used to shape the mesh by bending it in the cervical-occlusal and mesial-distal directions. Next, the mesh was attached to the tube surface by means of nine weld spots (Figure 1).

**Figure 1** – A: metal mesh. B: shaping of the mesh; C: orthodontic tube.




**Source:** The authors.

In the groups without salivary contamination (CB and MB), all the buccal surfaces of the enamel were etched with 37% phosphoric acid (Dentsply, Philadelphia, PA, USA) for 30 seconds and then washed for 60 seconds and dried. Acid etching was performed at the centre of the buccal surface, which was a standardised area corresponding to the size of the base. In the groups with salivary contamination (MB and MB-S), acid etching of the enamel surface was performed as described above and then non-stimulated saliva was applied by using a micro-brush (KG Brush, KG SORENSEN, Cotia, SP, Brazil). Unstimulated saliva was provided by one of the operators, who was instructed to brush the teeth using non-fluoride toothpaste before providing the saliva after one hour of fasting (CAMPOY; VICENTE; BRAVO, 2005; ASSAD-LOSS; TOSTES; MUCHA, 2012). After 10 seconds, the surface of the enamel was dried and the bonding procedure was performed (BISHARA *et al.*, 2002).

All the tubes were bonded by using orthodontic adhesive (Transbond XT®, 3M ESPE, St. Paul, MN, USA), which was applied to their base, and then buccally positioned to the buccal face of the crown by using orthodontic bonding tweezers (Morelli®, Sorocaba, SP, Brazil). The tubes were then compressed onto de centre of the buccal face with a force of 350 gf, which was standardised with a tensiometer (Morelli®, Sorocaba, SP, Brazil), until the excess adhesive was drained off (CACCIAFESTA *et al.*, 2003; IMANI *et al.*, 2018). All procedures were performed by the same operator (Table 1).

Next, the excess adhesive was removed and photo-activation was performed by using a polywave wireless LED device (Kavo Poly Wireless, Kavo do Brasil Indústria e Comércio Ltda, Joinville, SC, Brazil) operating at 1100 mW/cm$^2$ and regularly measured with a radiometer (Curing Radiometer Demetron, Danbury, CT, USA) during 20 seconds, with the tip being perpendicularly positioned to the orthodontic tube (IMANI *et al*., 2018).

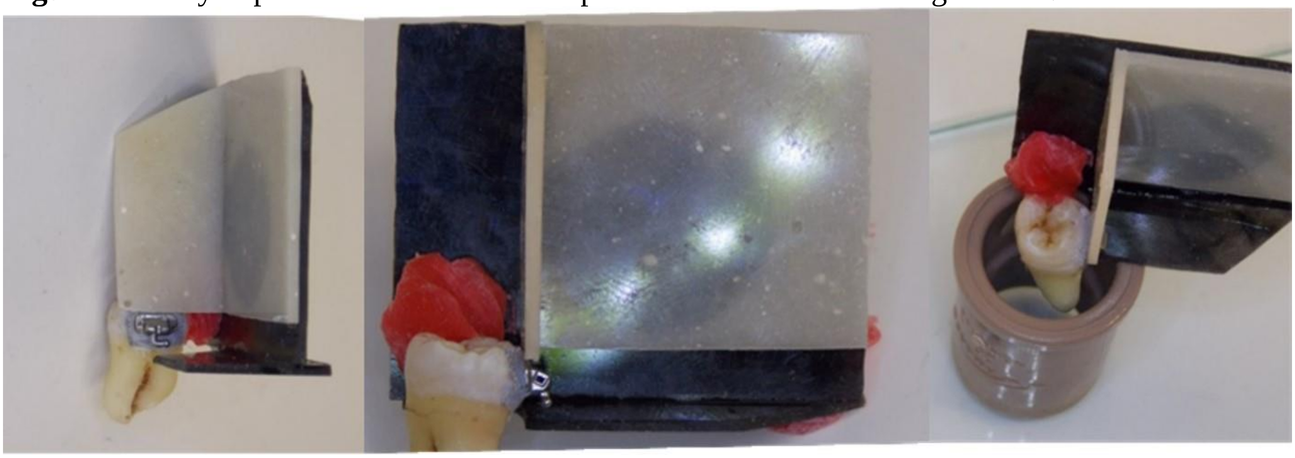
**Table 1 –** Composition and instructions regarding the use of orthodontic adhesive.

| Materials | Composition | Instructions for use |
|---|---|---|
| Transbond XT adhesive system (3M ESPE, St Paul, MN, USA) | TEGDMA, BisGMA, triphenylantimony, 4-(dimethylamine)-benzene-ethanol, camphorquinone, hydroquinone | Photo-polymerisation for 10 sec |
| Transbond XT composite resin XT (3M ESPE, St Paul, MN, USA) | BIS-GMA, silane, silica (70% weight), n-dimethyl benzocaine, hexaflurophosphate | Photo-polymerisation for 20 sec for metal brackets |

**Source:** The authors.

For manufacturing of the specimens, the teeth were centrally embedded in PVC rings (Amanco® NBR5648, Brazil) by using self-curing acrylic resin (Jet®, Atigos Odontológicos Clássico Ltda. Campo Limpo Paulista, S.P., Brazil) and an acrylic positioner, which was placed at the tooth's buccal face and upper part of the PVC ring so that the buccal face was perpendicularly positioned to the die base (ROMANO *et al.*, 2004) (Figure 2). Excess resin was removed with a Lecron spatula (Duflex SS White, São Cristovão, RJ, Brazil). After bonding the tubes, all the specimens were stored in distilled water at 37°C for three days.

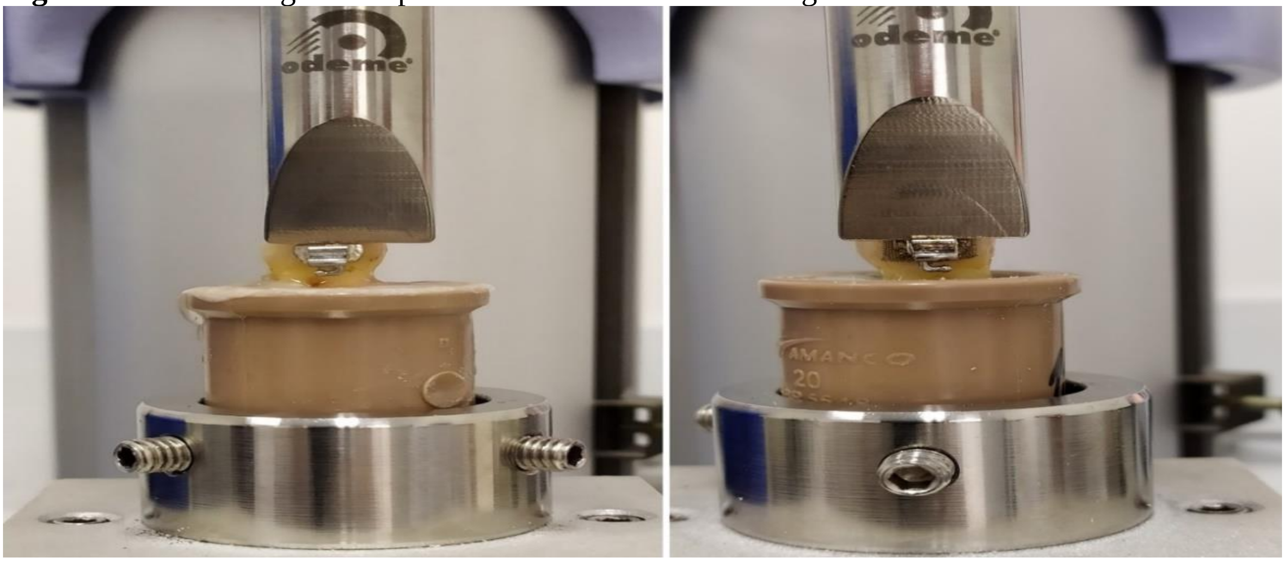
**Figure 2** – Acrylic positioner used to ensure parallelism of the tube being bonded.



**Source:** From the authors.

A universal testing machine (EZ-s Shimadzu®, Kyoto, Japan) was used for shear bond strength test, in which the specimens were positioned for application of force exerted by a chisel-shaped rod (Odeme Dental Research, Luzerna, Brazil) at a cross-speed of 0.5 mm/min. The set of holders were positioned so that they could exert shearing forces at the interface between tooth and tube (Figure 3). The results were obtained in kilogram force (kgf) and the shear bond strength was determined in Megapascal (MPa) considering the base area. Data were submitted to statistical analysis by using two-way analysis of variance (ANOVA) and Tukey's test at a significance level of 5%.

**Figure 3** – Positioning of the specimens in the universal testing machine.




**Source:** The authors.

The adhesive remnant index (ARI) was assessed by using an optical stereomicroscope (Stemi® 508, Zeiss, Germany) at 4X magnification. The amount of material adhered to the tube after debonding was rated in the Groups BC and BC-S according to ARI scores set by Artun & Bergland (1984). For Groups MB and MB-S, a different rating was used based on the condition of the metal mesh adhered to the tube.

## RESULTS AND DISCUSSION

The values of shear bond strength (SBS) obtained in the four experimental groups are shown in Table 2.

Statistical analysis of the results show that the groups using conventional tube without (CB) (17.6 ± 4.0 MPa) and with salivary contamination (CB-S) (13.8 ± 3.5 MPa) had values of SBS statistically higher than those of the groups using modified tubes without (MB) (7.6 ± 1.9) MPa) and with salivary contamination (MD-S) (8.0 ± 1.6 MPa), although Group CB was statistically superior than the others ($p < 0.05$). The presence of saliva interfered negatively with the mechanical behaviour of conventional tubes only ($p < 0.05$).

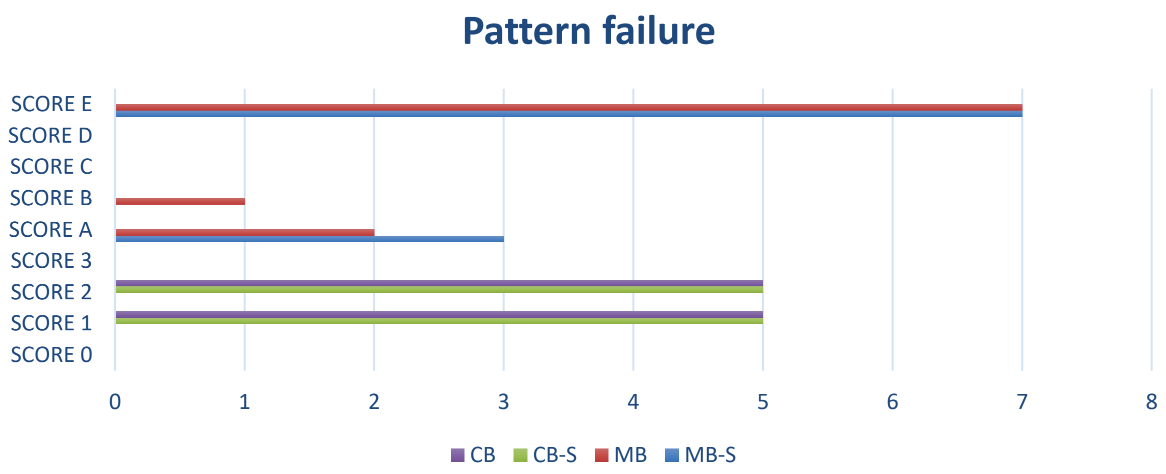
**Table 2 –** Composition and instructions regarding the use of orthodontic adhesive.

| Groups | SBS (MPa) | SD | 95% CI | |
|---|---|---|---|---|
| | | | IL | SL |
| CB | $17.6^{A}$ | 4.0 | 14.7 | 20.5 |
| CB-S | $13.8^{B}$ | 3.5 | 11.3 | 16.3 |
| MB | $7.6^{C}$ | 1.9 | 6.2 | 8.9 |
| MB-S | $8.0^{C}$ | 1.6 | 6.9 | 9.1 |

**Source:** The authors.

The failure pattern found for the four experimental groups is shown in Figure 4. For Groups CB and CB-S, there was a higher frequency of occurrence of ARI scores 1 (50%) and 2 (50%). On the other hand, Groups MB and MB-S had a predominance (70%) of mixed failure (score E).

**Figure 4** – Pattern of failure in the four experimental groups.




**Source:** The authors.

Despite the difficulty in obtaining human teeth, it was crucial to use newly-extracted human molars in order to reproduce the clinical situation as much as possible regarding the bonding of orthodontic tubes. With the use of bovine teeth, it would not be possible to mimic orthodontic bonding procedures as with posterior human teeth, which is the most critical region due to salivary contamination, thus requiring more control (KNOLL; GWINNETT; WOLFF, 1986). In addition, it is extremely important to reinforce the bonding of orthodontic accessories to molars as the rate of debonding involving these teeth is high (ZACHRISSON, 1977; MILLETT *et al.*, 2001; BANKS; MACFARLANE, 2007).

According to Zachrisson (1997), saliva contamination of the enamel surface is considered a cause of failure in orthodontic bonding, mainly in conventional adhesive systems in which a dry and clean surface is necessary for adequate bond strength. The presence of saliva can cause obliteration of canaliculi on the surface of the enamel, thus reducing the bonding area and also interfering with the penetration of resin. Therefore, when the micro-mechanical retention decreases the bond strength becomes compromised as a result (RAJAGOPAL; PADMANABHAN; GNANAMANI, 2004).

There are controversies in the literature regarding the influence of saliva on the shear bond strength of orthodontic accessories, since some studies have reported that such contamination increases the bond strength (OZTOPRAK *et al.*, 2007). Other authors (CACCIAFESTA *et al.*, 2003; SARI *et al.*, 2014), however, demonstrate that there is no interference with or significant decrease in the bond strength after salivary contamination (TURK *et al.*, 2007). The main justification related to these discrepant results refers to methodological variations in the use of artificial or natural saliva, composition and amount of saliva (MARIA *et al.*, 1995) and different bonding techniques.

Some methods have been proposed to minimise the influence of salivary contamination, such as the use of hydrophilic materials and whose behaviour is little, if any, affected by the surface moisture (ZACHRISSON, 1977; ELIADES *et al.*, 2000). In the present study, the adhesive system had not this characteristic as our objective was to assess the modification of the attachment base, both in dry and saliva contaminated environments, in order to improve or maintain the bond strength of orthodontic accessories. Nevertheless, it was possible to observe that salivary contamination interfered negatively with the bond strength values in the groups of conventional tubes, since statistically significant differences were found between Groups CB and CB-S. Moreover, moistened environment did not interfere with the results for modified bases (Groups MB and MB-S) either.

Another significant variable in posterior teeth is the absence of uniformity in the resin thickness beneath the tubes due to the presence of buccal sulci. In the present study, a tensiometer was used to standardise the pressure exerted onto the tubes so that the cementation thickness could be uniform in all specimens (CACCIAFESTA *et al.*, 2003; IMANI *et al.*, 2018).

It is known that the ideal adhesive material should have adequate bond strength to the tooth, and during debonding, should be removed without damaging the dental enamel by keeping its initial condition as much as possible (LAMPER *et al.*, 2014). The shear bond strength test is the method of choice to assess the efficacy of orthodontic adhesive systems (RIBEIRO *et al.*, 2008; MELGAÇO *et al.*, 2011; CÂMARA *et al.*, 2017). The scientific literature points out that the minimum value of shear bond strength for clinical use ranges from 5.9 to 7.8 MPa (REYNOLDS, 1975; REYNOLDS; VON FRAUNHOFER, 1977). Even though these values serve traditionally as a reference, their study has important limitations.

Transbond XT composite, which has been used by the majority of the studies for comparative assessment with other ones, was also used here as an adhesive agent (RIBEIRO *et al.*, 2008; MELGAÇO *et al.*, 2011; BERTOZ *et al.*, 2012). This composite is the gold standard material in several *in vitro* studies as it has bond strength values ranging from 7 to 19 MPa (RIBEIRO *et al.*, 2008; MELGAÇO *et al.*, 2011; CÂMARA *et al.*, 2017). By comparing the results of the present study with the reference values reported by Reynolds and von Fraunhofer (1977), as well as with previous studies using the same composite and orthodontic tubes modified by welding a metal mesh to their base (RIBEIRO *et al.*, 2008; MELGAÇO *et al.*, 2011; BERTOZ *et al.*, 2012), it was found that the bond strength values were very close to the minimum value set by Reynolds (1975), but lower than to those of more recent studies (RIBEIRO *et al.*, 2008; MELGAÇO *et al.*, 2011; CÂMARA *et al.*, 2017).

The results found in our study showed that welding a metal mesh to the pre-fabricated tube did not result in increased bond strength, which was significantly higher in the groups of conventional bases even in contact with saliva. This finding was similar to that of previous studies in which increase, or modification of the attachment area did not produce higher values of bond strength (TALPUR *et al.*, 2012). Therefore, it is suggested that the interpretation of any relationship between size of the base and debonding depends directly on the bonding method (TALPUR *et al.*, 2012).

The adhesive remnant index (ARI) was determined according to the scoring proposed by Artun and Bergland (1984) and since then has been used as a standard method elsewhere (ROMANO *et al.*, 2005; RASTELLI, 2010). In the present study, it was necessary to consider the surface of the tube because the metal mesh usually did not debond from the enamel surface completely in the Groups MB and MB-S. Therefore, it was not possible to evaluate the tooth's surface and these groups were assessed by using a new scoring system for the relationship between tube and mesh.

During the debonding of the tube, three types of failure may occur, namely: adhesive at the interface between composite resin and tube; cohesive in the composite resin; and adhesive at the interface between composite resin and enamel. A strong adhesion to the enamel can result in debonding at the interface between composite resin and enamel surface, causing fractures in the tooth, which would be an undesirable outcome (score 0) as damage to enamel would be more likely to occur (GRUNHEID; LARSON, 2019). At the end of the assessments, no occurrence of score 0 was observed in the present study.

However, in the Groups CB and CB-S, scores 1 and 2 occurred more predominantly and were equally distributed. Score 1 indicates that more than a half of the composite resin remained adhered to the tube, which represents a cohesive failure. The advantage of the present study is that there was less adhesive left to be removed from the enamel surface, thus reducing the likelihood of damage to the tooth during the use of rotary instrumentation (DUTRA *et al.*, 2009).

On the other hand, studies support that score 2 would be more favourable, and this corresponds to 50% in our study. This happened because less than a half of the composite resin was adhered to the tube, that is, there was more adhesive left on the enamel surface, which resulted in a safer process for debonding as the likelihood of tooth fracture was decreased (RETIEF, 1974; PENIDO *et al.*, 2008; PITHON *et al.*, 2008).

The behaviour of debonding was found to be different in the four groups. Tubes without welded metal mesh debonded from the enamel surface completely, whereas modified tubes had their metal mesh torn despite not being necessarily debonded at the interface between tube and mesh. Clinically, it is also speculated that this pattern of debonding can provide less discomfort to patients as the tubes do not detach completely.

From the results obtained, it was found that bond strength was actually weakened rather than improved despite the increased attachment area. Nevertheless, changes in the design and thickness of the orthodontic mesh might provide more satisfactory and beneficial results in terms of debonding pattern. Therefore, further studies are suggested to be conducted to test these modifications as other authors reported different results for tubes with different bases in their characteristics (LOPEZ, 1980; O'BRIEN; WATTS; READ, 1988).

In the clinical point of view, it might be advantageous to expand the attachment area by using a metal mesh as the modified tubes debonded in the majority of the cases and remained adhered to the tooth, which would cause less discomfort to the patient in the daily practice. Therefore, the results suggest that more studies should be carried out to assess whether the use of a thicker mesh could be more advantageous in avoiding tearing and providing better attachment and stability.

## CONCLUSION

The bond strength in conventional tubes was higher when compared to those with modified base. Nevertheless, it was found that salivary contamination during the bonding of modified tubes did not interfere with their bond strength, whereas such interference was observed in the conventional ones.

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