Original Article

In vitro study of shear bond strength in direct bonding of orthodontic molar tubes

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Abstract

Objective: Although direct bonding takes up less clinical time and ensures increased preservation of gingival health, the banding of molar teeth is still widespread nowadays. It would therefore be convenient to devise methods capable of increasing the efficiency of this procedure, notably for teeth subjected to substantial masticatory impact, such as molars. This study was conducted with the purpose of evaluating whether direct bonding would benefit from the application of an additional layer of resin to the occlusal surfaces of the tube/tooth interface. **Methods:** A sample of 40 mandibular third molars was selected and randomly divided into two groups: Group 1 - Conventional direct bonding, followed by the application of a layer of resin to the occlusal surfaces of the tube/tooth interface, and Group 2 - Conventional direct bonding. Shear bond strength was tested 24 hours after bonding with the aid of a universal testing machine operating at a speed of 0.5mm/min. The results were analyzed using the independent t-test. **Results:** The shear bond strength tests yielded the following mean values: 17.08 MPa for Group 1 and 12.60 MPa for Group 2. Group 1 showed higher statistically significant shear bond strength than Group 2. **Conclusions:** The application of an additional layer of resin to the occlusal surfaces of the tube/tooth interface was found to enhance bond strength quality of orthodontic buccal tubes bonded directly to molar teeth.

Keywords: Tooth bonding. Shear strength. Molar tooth.

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INTRODUCTION

There is currently a constant concern over the efficiency of clinical procedures performed in orthodontic practice. Orthodontists and patients alike, as well as their legal guardians, strive to attain the best possible results in the shortest possible treatment time. Among the factors that affect treatment time are the rebonding of brackets and recementing of bands. Frequent rebonding and/or recementing of accessories often hinders orthodontic mechanics, resulting in longer treatment time, higher costs and increased chair time.[12]

In many cases, orthodontists prefer to band teeth, especially molars and second premolars, to avoid the need to rebond accessories in these regions. However, it is a known fact that direct bonding saves chair time as it does not require prior band selection and fitting. Moreover, when the banding procedure is not performed with utmost care it can damage periodontal tissues (encroachment of biological width)[2] and/or dental tissues (infiltration at the tooth/band interface).

Current literature recommends that all teeth be bonded, underscoring the importance of assessing malocclusion severity and the need for anchorage devices.[17] Low profile molar tubes are available on the market which allow a 2 mm gain of vertical space in the area of posterior intercuspation.[17]

Despite its many advantages in terms of patient comfort, less periodontal damage and shorter chair time, direct bonding of molar teeth is not commonly performed in fixed orthodontic treatment. A 2002 U.S. study showed a higher prevalence of banded vs. bonded molars.[7] This finding is probably related to studies that evaluated the bonding of tubes, and demonstrated decreased bond strength[8] and increased percentage of clinical failures[3] in these tubes than in brackets bonded in the anterior region of the dental arch. Tubes bonded to molars using self-cure[3,18] or light-cure resins[9,10] showed around 14% of failure. According to the authors, these results may be related to (a) difficulty in maintaining proper isolation of the region, (b) inadequate adaptation of the attachment base to the tooth surface, (c) stronger masticatory forces, (d) different etching times, and (e) individual variations related to enamel composition.[8]

Nowadays, however, given recent advances in primer quality[4,16,17] and in the bases of orthodontic attachments[11] manufactured for direct bonding, combined with awareness of the benefits of this procedure, it would be convenient to devise methods capable of increasing the efficiency of traditional bonding, notably in teeth subjected to higher masticatory impact, such as lower molars. In reviewing the literature, only one study was found which evaluated in vitro an alternative approach to reduce the percentage of failures in the direct bonding of molars.[6] Johnston and McSherry[6] evaluated the effect of sandblasting of tube bases and concluded from the results that there was no significant increase in bond strength.

This study was therefore conducted with the purpose of evaluating whether direct bonding would benefit from the application of an additional layer of resin to the occlusal surfaces of the tube/tooth interface.

MATERIAL AND METHODS

A sample of 40 healthy third molars indicated for surgical removal were selected for this study.

The teeth were obtained in a private clinic and were cleaned and stored in 1% chloramine-T. The material was then embedded in rigid PVC rings with acrylic resin, only the crowns were exposed. When adding the material, the buccal surfaces of the crowns were positioned perpendicular to the base of the die with the aid of an acrylic square at an angle of 90° to ensure that the mechanical tests were performed correctly. After the resin had cured all samples were stored in distilled water.

The specimens were randomly divided into two groups according to different bonding protocols: Group 1 — conventional direct bonding with subsequent application of a layer of resin to the occlusal surface of each tube/tooth interface, and curing for a further 10 seconds over the reinforcement; Group 2 — conventional direct bonding, followed by application of an additional 10 seconds of curing by placing the light on the occlusal surface of the teeth.

For the sake of standardization all procedures were performed by a single orthodontist.

Prophylaxis of the buccal surface of each tooth was carried out with the aid of a rubber cup and extra-fine pumice prior to direct bonding, followed by rinsing with water and drying with compressed air. The teeth were then etched with phosphoric acid in gel at 37% for 30 seconds, after which the enamel was rinsed and dried. In Group 1, the etched area was larger, because the region where the resin reinforcement was applied needed etching. In the following step, Transbond XT primer (3M Unitek Orthodontic Products, Monrovia - CA, USA) was applied and the tubes (Morelli Ortodontia, Sorocaba - SP, Brazil) bonded directly to the teeth over an area of 13.6 mm^2, using Transbond XT light-cured resin (3M Unitek Orthodontic Products, Monrovia - CA, USA). The tubes were stored in their containers until the experiment had been completed, and were handled with bonding tweezers to avoid any contamination that might affect the results. The resin was applied to the basis of the tubes and then the set was placed in position. The tubes were positioned in the center of the buccal surface and then pressed firmly to obtain a thin layer of bonding material. All excess was carefully removed with the aid of an explorer probe before light curing, which was performed with a curing light (Ultraled - Dabi Atlante, Ribeirão Preto, Brazil, 10 VA power), with light intensity being measured by a 450 mW/cm^2 radiometer (Demetron Research Corp.) for 20 seconds, according to manufacturer's instructions.

Initially, direct bonding procedure was the same for both groups.

Immediately after conventional direct bonding, an additional layer of resin was applied to the tube/tooth interface in Group 1. A metal spatula was used to standardize the amount of resin applied. A mark was made 2 mm from the tip of the spatula and enough Transbond XT paste was applied to fill the space as far as the mark (Fig 1). The resin was then applied to the tube/tooth interface with the aid of a brush dipped in the adhesive, followed by curing for 10 seconds (Figs 2, 3 and 4). Ten seconds of light curing were applied to the reinforcement since the light was shone directly onto the additional resin, and according to the manufacturer's instruction this is the recommended curing time when using aesthetic brackets that allow the light directly onto the bonding material.

In Group 2 (Fig 5), after conventional direct bonding, 40 seconds were allowed to elapse before placing the curing light occlusally for another 10 seconds since total curing time in the experimental group was 30 seconds. This 40-second time was determined based on the

FIGURE 1 - Standardization of additional amount of resin applied to occlusal surfaces of tube/tooth interface in Group 1.

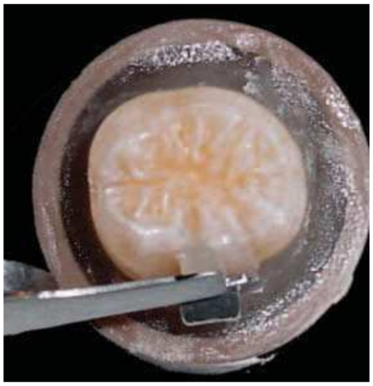

FIGURE 2 - Resin application to occlusal surface of tube/tooth interface in Group 1.

FIGURE 3 - Applying resin to occlusal surfaces of tube/tooth interface with aid of brush dipped in adhesive.

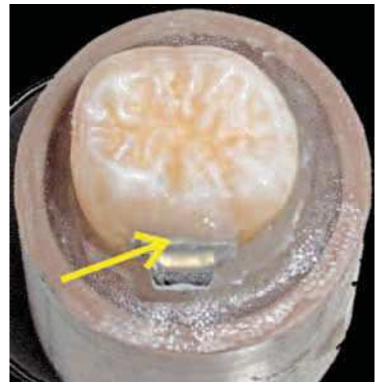

FIGURE 4 - Test specimens in Group 1: Conventional direct bonding followed by application of additional layer of resin to occlusal surfaces of the tube/tooth interface.

average time required for reinforcement application in Group 1.

After bonding, the specimens were stored in distilled water for 24 hours at a temperature of 37°C. After this period, the groups had their shear bond strength tested in a universal machine (EMIC, DL line, series 385, São José dos Pinhais, PR, Brazil) operating at a speed of 0.5 mm/min (Fig 6). The results were obtained in kilogram-force (kgf), converted into Newtons and divided by the tube base area, yielding results in MPa. The results obtained in MPa were recorded by the computer connected to the test machine upon bracket debonding.

Descriptive statistics was then performed: Means, standard deviations (SD), medians and minimum and maximum values.

The results were analyzed using Student's independent t-test. A 5% significance level was adopted.

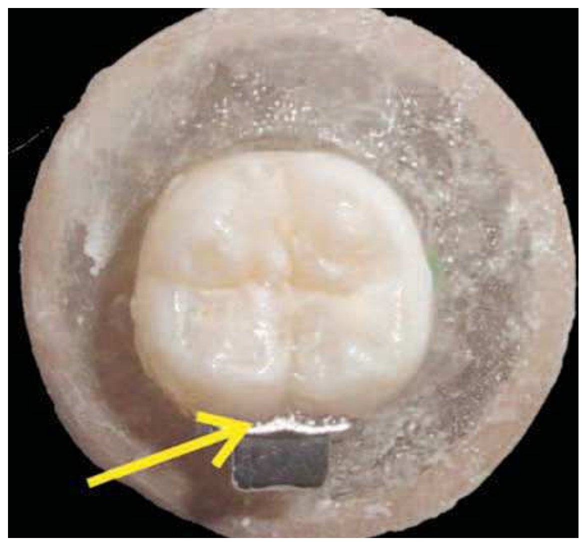

FIGURE 5 - Test specimens in Group 2: Conventional direct bonding, followed by additional 10-second light-curing.

RESULTS

Table 1 presents the mean values, standard deviations (SD), medians and minimum and maximum values, and kilogram-force MPa (kgf) at the time the tubes were debonded.

Group 1 showed a higher statistically significant shear bond strength than Group 2 (Table 2).

DISCUSSION

As a science, orthodontics has undoubtedly made enormous strides in recent decades. Advances in materials for direct bonding and cementation, in metal alloys used in orthodontic wires, orthodontic accessories, techniques, mechanics and anchorage devices have proven extremely relevant for treatment implementation.

FIGURE 6 - Position of the shear bond strength testing device.

TABLE 1 - Means, standard deviations (SD), medians and minimum and maximum values in MPa, and kilogram-force (kgf).

	Group 1		Group 2	
	MPa	Kgf	MPa	Kgf
Mean	17.08	23.69	12.60	17.48
SD	3.28	4.55	1.97	2.74
Median	16.35	22.66	13.1	18.16
Minimum	11.68	16.2	8.38	11.63
Maximum	24.54	34.03	15.68	21.75

TABLE 2 - Comparison between groups (independent t-test).

	Group 1	Group 2	p
Mean (MPa)	17.08	12.60	0.00*

* Statistically significant (p< 0.05).

However, despite all these improvements, most orthodontists have for decades banded molar teeth instead of directly bonding orthodontic tubes.[7] There is evidence in the literature that bonded molar tubes show a higher incidence of clinical failures than accessories that are bonded in more anterior regions of the dental arch.[10,18] However, it is essential to note that posterior teeth are subjected to greater masticatory efforts[15] and the occurrence of a higher percentage of clinical failures in this region is therefore perfectly justifiable. It should also be emphasized that there are no clinical studies showing that the banding of molars is more effective than directly bonding to these teeth. In conducting a longitudinal study to clinically evaluate the periodontium of banded vs. bonded molars, Boyd and Baumrind[2] found that banded maxillary molars had a higher incidence of clinical failures than bonded maxillary molars whereas the reverse was true to lower molars.

Today, with the development of orthodontic direct bonding materials, it seems more important to focus on clinical procedures that increase the bond strength of available materials. Therefore, the purpose of this study was to determine whether application of an additional layer of resin to the occlusal surface of the buccal tube/tooth interface increases the bonding quality of orthodontic tubes to molar teeth.

To this end, laboratory tests were performed in two groups: In Group 1, the experimental group, an additional layer of resin was applied to the occlusal surface of the tube/tooth interface, and in Group 2, the control group, after conventional direct bonding, the tube/tooth interface was light cured for an additional 10 seconds. Additional curing was applied to Group 2 in order to eliminate any variables related to curing time since the total time in Group 1, after applying the reinforcement, was 30 seconds.

According to resistance theory, when a force is applied to a body (tube), which is attached to another element (tooth) using a bonding material (resin), tension (T) is calculated by means of applied force (F) divided by contact area (A) (T = F / A). Considering that the resin — of all the elements involved in the tests — is the material with the lowest breakage stress, in order to increase the shear bond strength of the tube/resin/tooth complex we should increase the surface area. It was therefore with this purpose that the resin reinforcement was applied (Fig 7).

From these results it was possible to observe greater bond strength in Group 1, with a statistically significant difference compared to Group 2 (Tables 1 and 2). The additional layer of resin created an additional area of contact between tooth and tube and thus the applied force was divided by a more extensive area, yielding better results for this group.

The mean value found for Group 2 (control) is similar to results obtained by Knoll, Gwinnett and Wolf,[8] who noted a bond strength of 11±4 MPa, and Bishara et al,[1] who found a mean value of 11.8±4.1 MPa.

Upon completion of this study, a third group was outlined whose teeth had only received conventional direct bonding of tubes with a total curing time of 20 seconds. The results showed a statistically significant difference compared to the group that received reinforcement during bonding but were similar to the group that received the additional 10-second light-curing.[14]

Proffit, Fields and Nixon[15] showed that in balanced faces, posterior teeth are subjected to greater masticatory forces, with forces of around 30 kg being exerted. In this study, the mean force in kilogram-force at the time of debonding the tubes in Group 1 was 23.69 kgf (Table 1), a value closer to what Proffit, Fields and Nixon[15] found than to the value obtained in Group 2 (17.48 kgf, Table 1).

Since most of the factors involved in the procedure of directly bonding molar tubes cannot be changed by the orthodontist (salivation, difficult access to the bonding procedure, absence of uniform buccal surfaces and resin thickness, initial patient age and the occurrence of occlusal interference),[9] this alternative method proposed for performing this procedure seems to increase the clinical quality of the direct bonding of orthodontic tubes.

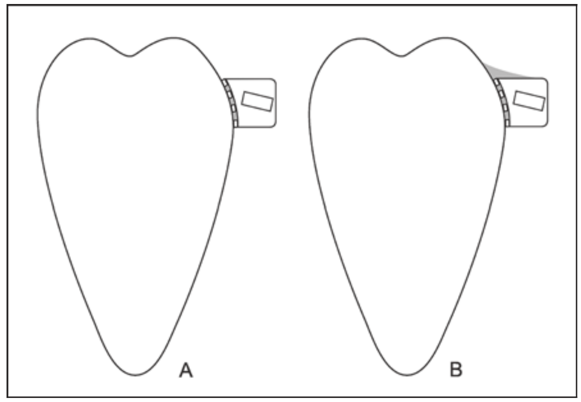

FIGURE 7 - **A**) Conventional direct bonding; **B**) Enlargement of resin area to increase bond strength of whole tube/resin/tooth set.

Moreover, in assessing in vivo tubes bonded by means of the conventional method of bonding to molars using self-etching primer and Transbond XT resin, Pandis et al[10] observed that the first failure occurred after 23 months on average (20 to 26 months). Since in this study the group with reinforced resin showed better bond strength than the group with conventional bonding, probably the time for observation of clinical failure with the aid of the resin reinforcement will be longer than this period, when the most orthodontic cases are already finished.

Despite the fact that adhesive products have a rough surface that favors the accumulation of plaque,[18] the region where the additional layer of resin is applied can be easily cleaned by the patient and controlled by professionals during consultations. Besides, it is located far from the gingival margin, causing no damage to periodontal tissues.

Before deciding between banding or bonding molars several factors should be evaluated such as the quality of the adhesive material used for direct bonding, the substrate (amalgam, resin, porcelain, enamel, metal alloys) and the clinical needs (type of movement, clinical crown height, need for installation of anchorage devices).[2,17,18] After careful consideration of these factors, if the choice falls on direct bonding, the method proposed in this study appeared to increase effectiveness.

The adhesive remnant index was not calculated because the aim of this study was to evaluate a new approach to bonding orthodontic molar tubes and not to evaluate the bonding system.

Despite the high values obtained in this study, only one specimen sustained enamel fracture while the tubes were being debonded. The fracture occurred in the tooth that exhibited the highest value during shear testing (34.03 kgf, 24.54 MPa, Table 1). However, it is important to emphasize that recent studies comparing in vivo with in vitro bond strength have shown that the values obtained in vivo proved to be significantly lower than those obtained in vitro.[5,13] Based on the results, Penido et al[13] stressed the importance of evaluating the acceptable values of bond strength of orthodontic accessories obtained through mechanical testing.

The amount of additional layer of resin used in this in vitro study represents a fixed value for comparison between groups. Based on these results, one can infer that the amount of resin was effective in increasing shear bond strength. However, for clinical use of this method, the authors recommend to quantify the bonding material so as not to interfere with the occlusal relationship between upper and lower molars.

A clinical investigation is currently under way to ascertain the findings of this laboratory study since during bonding no saliva contamination occurred and neither were there any difficulties placing the tubes in the posterior region. Therefore, laboratory test results may be better than those achieved in clinical research. However, it is important to emphasize that, although none of the groups was affected by the above mentioned problems, group 1 showed the best results.

CONCLUSIONS

Based on the results of this study, application of an additional layer of resin to the occlusal surfaces of the tube/tooth interface enhanced bond strength of orthodontic buccal tubes bonded directly to molar teeth.

REFERENCES

1. Bishara SE, Gordan VV, VonWald L, Olson ME. Effect of an acidic primer on shear bond strength of orthodontic brackets. Am J Orthod Dentofacial Orthop. 1998;114(3):234-7.
2. Boyd RL, Baumrind S. Periodontal considerations in the use of bonds or bands on molars in adolescents and adults. Angle Orthod. 1992;62(2):117-26.
3. Geiger A, Gorelick L, Gwinnett AJ. Bond failure rates of facial and lingual attachments. J Clin Orthod. 1983;17(3):165-9.
4. Giannini C, Francisconi PAS. Resistência à remoção de braquetes ortodônticos sob ação de diferentes cargas contínuas. Rev Dental Press Ortodon Ortop Facial. 2008;13(3):50-9.
5. Hajrassie MKA, Khier SE. In-vivo and in-vitro comparison of bond strengths of orthodontic brackets bonded to enamel and debonded at various times. Am J Orthod Dentofacial Orthop. 2007;131(3):384-90.
6. Johnston CD, McSherry PF. The effects of sanblasting on the bond strength of molar attachments - an in vitro study. Eur J Orthod. 1999;21(3):311-7.
7. Keim RG, Gottlieb EL, Nelson AH, Vogels DS 3rd. JCO study of orthodontic diagnosis and treatment procedures. Part 1: results and trends. J Clin Orthod. 2002;36(10):553-68.
8. Knoll M, Gwinnett AJ, Wolff MS. Shear strength of brackets bonded to anterior and posterior teeth. Am J Orthod Dentofacial Orthop. 1986;89(6):476-9.
9. Millett DT, Hallgren A, Fornell AC. Bonded molar tubes: A retrospective evaluation of clinical performance. Am J Orthod Dentofacial Orthop. 1999;115(6):667-74.
10. Pandis N, Christensen L, Eliades T. Long-term clinical failure rate of molar tubes bonded with a self-etching primer. Angle Orthod. 2005;75(6):1000-2.
11. Park DM, Romano FL, Santos-Pinto A, Martins LP, Nouer DF. Análise da qualidade de adesão de diferentes bases de braquetes metálicos. Rev Dental Press Ortodon Ortop Facial. 2005;10(1):88-93.
12. Pasquale A, Weinstein M, Borislow AJ, Braitman LE. In-vivo prospective comparison of bond failure rates of 2 self-etching primer/adhesive systems. Am J Orthod Dentofacial Orthop. 2007;132(5):671-4.
13. Penido SMMO, Penido CVSR, Santos-Pinto A, Sakima T, Fontana CR. Estudo in vivo e in vitro com e sem termocliclagem, da resistência ao cisalhamento de braquetes colados com fonte de luz halógena. Rev Dental Press Ortodon Ortop Facial. 2008;13(3):66-76.
14. Pinzan-Vercelino CRM, Pinzan A, Gurgel JA, Bramante FS, Pinzan LM. In vitro evaluation of an alternative method to bond molar tubes. J Appl Oral Sci. 2011;19(1):41-6.
15. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long-face adults. J Dent Res. 1983;62(5):566-71.
16. Rosa CB, Pinto RA, Habib FAL. Colagem ortodôntica em esmalte com presença ou ausência de contaminação salivar: é necessário o uso de adesivo auto-condicionante ou de adesivo hidrofílico? Rev Dental Press Ortodon Ortop Facial. 2008;13(3):34-42.
17. Trevisi H. Sistema individualizado de posicionamento de braquetes. In: Trevisi H. SmartClip: tratamento ortodôntico com sistema de aparelho autoligado: conceito e biomecânica. Rio de Janeiro: Elsevier; 2007. p. 71-123.
18. Zachrisson BU. A posttreatment evaluation of direct bonding in orthodontics. Am J Orthod. 1977;71(2):173-89.

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