Review Article

Molar tubes and failure rates – A review

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Abstract: Objectives: To review the failure rates of molar tubes and the effect of molar tube base design, adhesive type, and bonding technique on the failure rates of molar tubes. Data: The revolution of molar bonding greatly impacted fixed orthodontic appliance treatment by reducing chair-side time and improving patient comfort. Even with the many advantages of molar bonding, clinicians sometimes hesitate to use molar tubes due to their failure rates. Sources: Internet sources, such as Pubmed and Google Scholar. Study selection: studies testing the bond failure rate of molar tubes. Conclusions: The failure rate of the molar tubes can be reduced and the bond strength of the molar tubes can be improved by changing the design of the molar tube base, the adhesive type, and the bonding technique.

.**Keywords:** molar tubes, bond failure, bonding technique, bonding adhesive, base design

Introduction

A molar tube is a terminal attachment in the shape of a metal tube bonded on the buccal surface of molars through which the archwire slides as the teeth move (1). They can be categorized based on the mode of attachment as weldable (welded onto bands) and bondable (bonded to the tooth surface) (Figure 1), based on the lumen shape as round, oval, and rectangular (Figure 2), based on the number of tubes as single, double, and triple (Figure 3), and based on the technique/prescription as Begg tube, Edgewise tube (0° tip and torque values), and pre-adjusted edgewise (with prescribed in-out, tip, and torque values) (2):

Figure 1: Types of molar tubes based on the mode of attachment. (A) weldable molar tubes (B) bondable molar tubes (3).

Figure 2: Types of molar tubes based on lumen shape. (A) round (B) oval (C) rectangular [2].

Figure 3: Types of molar tubes based on the number of tubes. (A) Single (B) Double (C) Triple [4].

Bonding of Molars

In the past, orthodontists preferred to band molar teeth during fixed appliance therapy. But more recently, the popularity of molar tubes has increased and become a routine procedure, especially with the evolution of adhesive systems [5-8].

Molar bonding has multiple advantages over banding. These advantages include; better oral hygiene can be maintained [8], therefore, less plaque accumulation, gingival inflammation, and periodontal problems [9,10], no need for antibiotic prophylaxis in patients at risk from bacteremia [6], more patient comfort by eliminating painful banding experiences [11,12], eliminating the need for separators and the spaces caused by the bands [6], better esthetic [13-15], reducing the chairside time and allowing completion of the bonding procedure in a single visit [16,17], and allowing easier detection of caries [14,15].

The most important disadvantage of molar bonding is the failure of bonding which tends to delay treatment time, which is considered a primary concern for most orthodontists and patients looking for orthodontic treatment. Another disadvantage of molar bonding is the higher rate of enamel decalcification and white spot lesion formation with bonding molars than with banding [7,8,12,18-21]. The molar tubes and the bonding adhesives provide a retentive site for plaque accumulation and this new site is susceptible to caries [22-24].

Bond Failure

Despite the advantages of direct bonding of molars in terms of comfort, shorter chair time, and minor periodontal damage, a lot of orthodontists still prefer to band molars in orthodontic treatment due to the better reliability of molar bands and higher bond failure of molar tubes (8,19,25,26). Attachments bonded to molars showed a lower bond strength and a higher clinical failure rate than those bonded to teeth more anteriorly in the arch (5,28-30). The difficulty in achieving adequate moisture control during bonding, the high masticatory forces on molars, the different etching patterns, the inadequate adaptation of the molar tube base causing an uneven adhesive layer, the differences in acid-etching times, and individual variations in enamel composition are potential factors of bond failure (12,14,18,28-32).

Failure Rates

In the early years of bonding molars, bonded molar tubes were found to have a high failure rate (up to 30%) when compared with bonded brackets on other teeth (5,6). In 1999, **Millett *et al.*** did a retrospective study and analyzed patients' records. They found the overall failure rate was 21%, with 22% in the maxillary molars and 20% in the mandibular molars (33). In 2001, **Millett *et al.*** reported that molar tubes bonded with either a light-cured or a chemically-cured resin adhesive had shown failure rates greater than 21% (29). In 2005, **Pandis *et al.*** recorded a total failure rate of 14.80% with the greatest failure rates in the second molars on all quadrants (34). In 2007, **Banks and Macfarlane** compared the failure rates of molar tubes and molar bands and found that the molar tubes had twice the failure rates of the bands. The failure rates of molar tubes varied from 14.8% to 29.5% (6). In 2011, **Nazir *et al.*** found that molar tubes placed on the first permanent molars during fixed orthodontic appliance treatment have higher failure rates than bands (19). In 2014, **Jung** tested failure rates of brackets and molar tubes in young (under 18 years) and older patients (over 18 years). He found no significant difference in the failure rates of molar tubes when the first molars are compared to the second molars. He also found that failure rates of molar tubes were higher in younger patients (15.3%) than in older ones (5.2%) (35). In 2016, **Oeiras *et al.*** compared the failure rates of molar tubes and molar bands. After 12 months of follow-up, they found that banded molars had a failure rate of 30.5% and bonded molars had a failure rate of 28.8%. The bonded molar tubes showed the first bond failure in the first two months, whereas the bands showed the first failure within three months (8). In 2018, **Gupta and Mahanta** reported that the failure rates of molar tubes were more than the failure rates of brackets on premolars, canines, and incisors. They also found that the failure rates were greater in the upper right second molars and upper left first molars (10).

Discussion

The Effect of Base Design on Failure Rates

Manufacturers have improved the mechanical retention of molar tubes by introducing undercuts in cast molar tube bases or by welding mesh wires of varying diameters to the base and incorporating different designs in the mesh itself. Other techniques to enhance retention include; structuring bases using laser, sandblasting, plasma-coated metal bases, and fusing the bases with metal or ceramic particles (6,36-39) (Figure 4).

In 2013, **Matasa** found that the most significant influencing factors concerning the mesh design are the wire diameter of the mesh and the mesh number (the number of openings per unit of area of the mesh). Mesh bases provided greater shear bond strength with larger mesh spaces (apertures) than bases with smaller mesh apertures. Air needs to have the ability to escape the base for the resin to penetrate effectively and this is influenced by the free volume between the attachment base and the mesh (36,39,41).

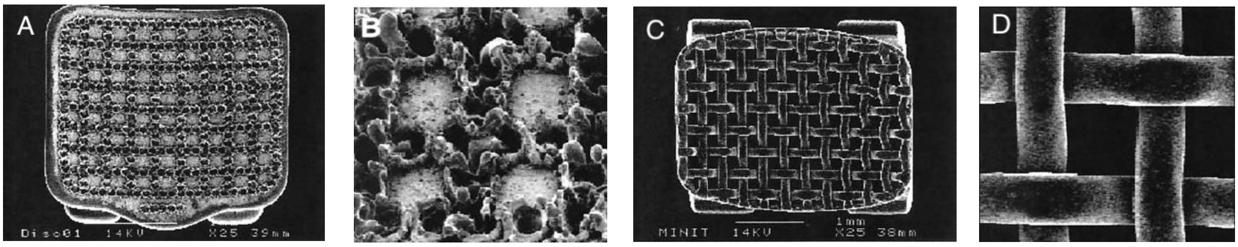

Figure 4: Bracket bases under an electron microscope with X25 magnification in (A) and (C) and X200 magnification in (B) and (D). (A) and (B) laser-structured bracket base. (C) and (D) a simple foil mesh bracket base (40).

Base design refinement and improved adhesive systems allowed the manufacturers to decrease the size of the molar tube without affecting bond strength (6,36,38,39,41). In 2012, **Talpur *et al.*** conducted a study to test the relationship between bond strength and molar tube base surface area. The molar tubes tested had different base surface areas and different profiles. No statistically significant relationship was found between bond strength and molar tube base surface area (42).

The Effect of Adhesive Type on Failure Rates

The adhesive should be strong enough to keep the molar tube attached to the tooth surface and resist tensile, shear, torque, and functional stresses during the orthodontic treatment. Still, it should not be too strong that causes damage to the enamel when the tube is removed. The enamel fracture causes staining and plaque accumulation on the rough surface (40,43-45). There are different types of orthodontic adhesives with different values of bond strength depending on the properties of the material (33,46).

When comparing chemically-cured and light-cured composites, no statistically significant differences in bracket failure rates were reported. But when comparing chemically-cured composite and chemically-cured conventional glass ionomer cement, the latter showed statistically significantly higher failure rates than the chemically-cured composite (47-49).

In 2000, **Millett *et al.*** reported no statistically significant differences between compomer and composite failure rates (50). In 2004, **Aljubouri *et al.*** found no significant difference, clinically and statistically, between the bond failure rate of the self-etching primer and the two-stage (etch and primer) bonding system. This was supported by similar results by **Banks and Thiruvenkatachari** (51,52). In 2005, **Pandis *et al.*** conducted an *in-vivo* study to assess the failure rates on molar tubes bonded with 3M Transbond Plus self-etching primer on the first and second molars. Molar tubes bonded on first molars with self-etching primer showed failure rates comparable with those for tubes bonded with conventional acid etching (34). In 2019, a study by **Tanbakuchi *et al.*** revealed that the addition of amorphous calcium phosphate to resin-modified glass ionomer cement significantly decreases the shear bond strength of molar tubes compared to the conventional resin bonding system [53]. In 2021, **Griffin *et al.*** conducted an *in-vitro* study comparing the shear bond strength of four adhesive systems. The adhesive systems included one etch-and-rinse adhesive system and two all-in-one adhesives. Still, enamel was acid etched before applying adhesives, and one new all-in-one bonding agent (8th generation) together with a traditional adhesive used to bond molar tubes. All adhesives showed acceptable shear bond strengths for clinical use, without any significant differences in shear bond strengths when used to bond molar tubes [54].

The Effect of Bonding Technique on Failure Rates

Despite the recent advancements in increasing the retentive strength of orthodontic adhesive systems and reducing the failure rate of orthodontic attachments, it may be more important to improve the procedure of bonding, especially for molars that are subjected to high occlusal forces [5,15]. Many *in-vitro* studies have tested different bonding techniques that might reduce the frequency of molar bond failures. **Johnston and McSherry (1999)** reported that sandblasting the foil mesh base of the molar tube provided only a minimal improvement in clinical performance [55]. **Pinzan-Vercelino *et al.* (2011)** conducted an *in-vitro* study. They observed that applying an additional layer of adhesive at the occlusal molar/tube interface increased the shear bond strength of the molar tube [15] (Figure 5). **Nascimento *et al.* (2014)** did an *in-vivo* study. They reported that adding an adhesive layer at the molar/tube interface provides higher bond strength than can be achieved with conventional direct bonding [12].

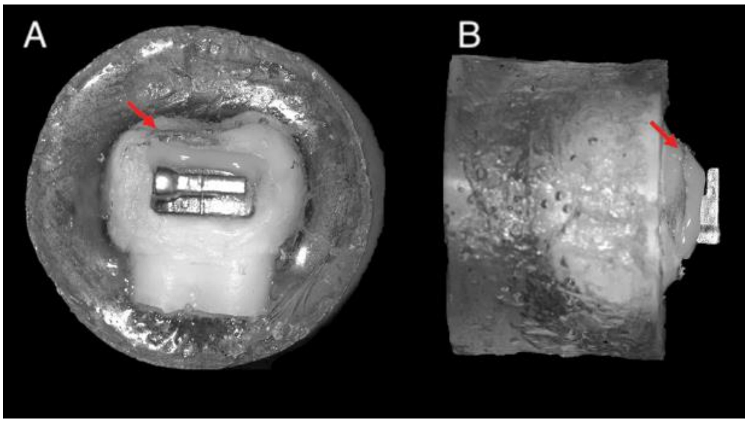

Figure 5: A molar tube bonded with an additional layer of resin (red arrow) in the buccal (A) and occlusal (B) view [17].

In 2017, **Abu Alhaija *et al.*** studied the effect of silane-coating of molar tube bases and enamel micro-abrasion (18% hydrochloric acid and pumice) on the shear and tensile bond strengths of molar tubes. The greatest shear and tensile bond strengths were reported in molar tubes bonded to molars pre-treated with micro-abrasion before the conventional acid etching with the addition of silane to the molar tube bases. While molar tubes bonded to molars pre-treated with micro-abrasion only and molar tubes bonded to molars pre-treated with micro-abrasion with the addition of silane to the molar tube bases without the conventional acid etching; recorded bond strength values similar to that of the molar tubes bonded to molars etched with 37% phosphoric acid gel [56]. In 2020, **Ganiger *et al.*** investigated the effect of sandblasting enamel surface instead of acid etching on the bond strength. They found that sandblasting using 50μ aluminum oxide particles instead of the acid etching technique improved the bond strength. Moreover, sandblasting using 100μ aluminum oxide particles recorded higher bond strength than 50µ particles [57]. In 2020, **Jardim *et al*.** conducted an *in-vitro* study and found that using flowable resin adhesives as a bonding reinforcement (the additional adhesive layer at the molar/tube interface) does not provide a significant increase in the bond strength of the molar tubes [17].

Conclusion

With the advancement of enamel bonding techniques, molar tubes have become more popular among orthodontists. The main setback of molar bonding was the high failure rates of molar tubes which lengthened the treatment time and increased the number of emergency visits. Changes in the molar tube base design, adhesive type, and bonding technique have improved the bond strength of molar tubes and reduced failure rates. The base design of molar tubes was improved by incorporating undercuts in the base design and welding mesh wires of different sizes in the molar tube base. Composite resins are still superior to other types of adhesives. The bonding technique was improved by sandblasting, enamel micro-abrasion, and adding an adhesive layer at the occlusal molar/tube interface.

Conflict of interest: None

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العنوان:الانابيب الضرسية ومعدلات الفشل - مراجعة

الباحثون: نوار محمد حسن، ياسر عبد الكاظم ياسر، كرانت مكنتاير

المستخلص:

الأهداف: مراجعة معدلات فشل الأنابيب الضرسية وتأثير تصميم قاعدة الأنبوب الضرسية ونوع المادة اللاصقة وتقنية اللصق على معدلات فشل الأنابيب الضرسية. البيانات: كان لثورة اللصق الضرسي تأثير كبير على العلاج بأجهزة تقويم الأسنان الثابتة من حيث تقليل وقت الجلوس بجانب الكرسي وتحسين راحة المريض. حتى مع المزايا العديدة للصق الضرسي، يتردد الأطباء أحيانًا في استخدام الأنابيب الضرسية بسبب معدلات فشلهم. المصادر: مصادر الإنترنت، مثل Pubmed وGoogle Scholar. اختيار الدراسة: دراسات تختبر معدل فشل اللصق للأنابيب الضرسية. الخلاصة: يمكن تقليل معدل فشل الأنابيب الضرسية ويمكن تحسين قوة اللصق للأنابيب الضرسية عن طريق تغيير تصميم قاعدة الأنبوب الضرسي ونوع المادة اللاصقة وتقنية اللصق.