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Review Article

Orthodontic bracket bonding techniques and adhesion failures

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ABSTRACT

The introduction of glass ionomer cements in orthodontics aimed to address the drawbacks of the acid-etch technique using composite resins, including demineralization, enamel damage, and potential allergic reactions. These cements release fluoride over time, potentially protecting against demineralization. Glass ionomer cements, despite their benefits in reducing adhesive residue and protecting against demineralization, showed higher bond failure rates compared to composite resins. This is attributed to their sensitivity to application techniques and moisture, along with a delayed setting time. In contrast, light-cured composite resins, preferred over chemically-cured resins in recent years, offer advantages such as ease of use, consistent handling, and controlled setting. However, early trials indicated higher bond failure rates for light-cured resins, a finding not consistently replicated in later studies. While glass ionomer cements offer certain advantages, their higher bond failure rate poses a significant limitation. Light-cured composite resins, with their user-friendly characteristics, have become the preferred choice in orthodontic bonding despite initial concerns about higher bond failure rates.

Keywords: Orthodontic bracket bonding, Adhesion failures, Direct bonding, Indirect bonding

INTRODUCTION

The ideal orthodontic treatment is characterized by attaining the desired outcomes within a designated time frame and through a specified number of appointments.[1] The cornerstone of successful treatment is ensuring that the brackets, which are crucial for aligning teeth, stay firmly bonded throughout the treatment period. However, challenges arise when bracket bonding fails. These failures, prevalent in about 3.5% to 10% of cases, can significantly prolong the treatment duration.[2] This not only leads to higher direct and indirect costs but also contributes to patient dissatisfaction.[3,4] Therefore, maintaining the integrity of bracket bonding is essential for both the efficiency and effectiveness of orthodontic treatment.

Direct bonding (DB) is a commonly employed method for affixing fixed devices in orthodontics.[5] However, his technique has its drawbacks, frequently affected by the manual skill and professional expertise of the practitioners and their degrees of fatigue and stress.[2] To address these inconsistencies, the practice of orthodontics has gradually adopted the indirect bracket bonding technique (IB).[6] This technique involves several stages; first, clinical stage I, where models of the patient's dental arches are obtained; followed by a laboratory stage, during which the placement of orthodontic accessories is established, these accessories are fixed onto the models, and a transfer tray is constructed; and concluding with clinical stage II, where the accessories are transferred and adhered to the patient's teeth.[7]

There are both benefits and drawbacks linked to IB. For the practitioner, this method provides enhanced visualization and increased precision in bracket placement,[8] and for the patient, it decreases chair time.[5] Conversely, IB is more expensive due to the required laboratory procedures.[7] Moreover, the transfer of brackets can lead to an excessive layer of orthodontic resin beneath them, possibly disrupting their positioning. This can result in inadequate leveling and alignment, ultimately extending the treatment duration.[2] With the advancement of technologies like computer-aided design and manufacturing (CAD-CAM), there is a renewed interest in IB. CAD-CAM technology enables the creation of 3D models of the maxilla and mandible, along with the swift fabrication of prototype transfer jigs for relocating brackets with tailor-made custom resin bases.[6]

However, the choice between IB and DB in clinical practice is not straightforward. Some studies suggest that DB is more efficient than IB,[9] while others indicate that IB performs better in terms of bracket adhesion failures.[10] However, certain studies indicate that there are no significant distinctions between these two techniques.[2]

METHODS

This study is based on a comprehensive literature search conducted on 23 December 2023, in the Medline and Cochrane databases, utilizing the medical topic headings (MeSH) and a combination of all available related terms, according to the database. To prevent missing any possible research, a manual search for publications was conducted through Google Scholar, using the reference lists of the previously listed papers as a starting point. We looked for valuable information in papers that discussed orthodontic bracket bonding techniques and adhesion failures. There were no restrictions on date, language, participant age, or type of publication.

DISCUSSION

Adhesives

Composite resin versus glass ionomer cement

The introduction of glass ionomer cements for bonding orthodontic brackets was aimed at mitigating the adverse effects associated with the acid-etch technique using composite resins. These adverse effects include demineralization, enamel damage during debonding, challenges in adhesive residue removal, and potential allergic reactions to these adhesives.[11] Glass ionomer cements are known to serve as temporary fluoride reservoirs, releasing fluoride over time,[12] which could offer protection against demineralization. However, studies from two randomized trials indicate that bond failures with glass ionomer cement are significantly higher than those with composite resins, with failure rates of 33 to 35% compared to 15%.[13,14] The higher failure rate of glass ionomer cements can be attributed to several factors, such as sensitivity to application technique, susceptibility to moisture, and delayed setting.

Conversely, the use of glass ionomer cement is linked to notably less adhesive residue, thereby reducing the time needed for cleaning compared to composite resin. This advantage is due to the cement's tendency to flake off after use, leaving only minimal residue on the enamel, which can be easily removed using a tungsten carbide bur.[11] Scanning electron microscope studies have further corroborated these observations of glass ionomer cement on enamel surfaces (52). Therefore, despite some drawbacks, glass ionomer cements exhibit certain characteristics that may make them beneficial as bonding agents in orthodontic applications.

Chemically-cured versus light-cured composite resins

In recent decades, light-cured composite resins have gained prominence in dentistry, surpassing chemically-cured autopolymerizing resins. Their ease of use, versatility, and prolonged working time make them advantageous for detailed tasks such as bracket placement and the removal of excess material. Light-curing also offers consistent handling properties and a controlled setting, facilitating the smooth insertion of archwires.[11]

One of the earlier randomized trials comparing the two types of resins for bonding metal brackets found a notably higher bond failure rate with light-cured resins at 24.3% compared to chemically-cured resins at 12.4%.[15] However, this trial compared a fluoride-releasing light-cured resin to a conventional chemically-cured resin, resulting in an overall bond failure rate of 18.4%- significantly higher than the average rates reported in the literature (approximately 6 to 10%). Another research comparing the two resins used for bonding metal brackets also found no statistically significant difference in the rates of bond failure.[16] Furthermore, a third study comparing the resins used for bonding polycrystalline ceramic brackets similarly reported no significant differences in the rate of bond failure.[17]

These findings have contributed to the widespread adoption of light-cured composite resins for orthodontic bonding, preferred over chemically-cured adhesives in the last decade.[11]

Curing lamps

The advent of light-cured resins in orthodontic bonding brought widespread use of blue halogen curing lamps, but their efficiency is compromised by multiple factors. Firstly, only a small fraction of their emitted energy is utilized as light, with the majority being heat. Secondly, these lamps initially produce white light, which is then filtered to blue, reducing energy efficiency. Over time, the light output from these lamps decreases, further diminishing their effectiveness. Additionally, the longer curing times required for each tooth not only extend the procedure but also heighten the risk of moisture contamination, a critical concern in orthodontic bonding processes.[11] Recently, more efficient alternatives like light-emitting diodes (LEDs) and plasma arc lights have been developed. These newer systems offer benefits like reduced heat generation during curing, enhanced durability, consistent intensity over time, and higher emission intensity, but at a higher initial cost.

A systematic review of randomized clinical trials, which compared bond failure rates across halogen, LED, and plasma arc lighting systems, found no significant differences in bond failures among these systems.[18] Notably, time savings were observed with LED and particularly plasma arc lamps, requiring only nine seconds or five seconds per bracket respectively, compared to 20 seconds with halogen lamps. However, interpreting these findings requires caution due to the variability in bonding protocols in the trials, including differences in bracket type, adhesive materials, etching duration, and observation periods.[11]

General characteristics of bond failure

In the realm of orthodontic treatments, bracket failure rates, as observed in long-term studies, both randomized and non-randomized, typically fluctuate between 6.0% and 8.0%. It is noteworthy that nearly half of all patients (47-58%) experience at least one bracket failure during their treatment course.[19]

Within this subset of patients, about one-third encounter only a single bracket failure, while the majority, approximately two-thirds, undergo multiple bracket failures. Gender differences in bond failures have been explored, but the results have been inconsistent, showing varying failure risks for males and females.[11]

Age also appears to play a role in bracket failure rates, with initial studies suggesting that older patients tend to have lower failure rates than younger ones. However, these early findings were later challenged by the same researchers. Regarding the location of failures, there is a noticeable disparity between the upper and lower jaws. Lower teeth generally exhibit both earlier and more frequent failures than upper teeth, often attributed to factors like increased chewing stress, regular occlusal contact, and challenges in maintaining a dry environment during bonding.[11]

The side of the mouth seems to have a minimal impact on bond survival. One study noted marginally higher failure rates on the patient's left side but only for upper teeth, possibly due to the right-handedness of the clinicians involved in the study.[20] The likelihood of bond failure also differs between anterior and posterior teeth, with anterior teeth, particularly canines, showing lower failure rates than premolars and molars.[11] The highest failure rates have been observed in specific teeth such as tooth 45 and tooth 35, according to the Fédération Dentaire Internationale numbering system, with rates reaching up to 22.7% and 23.6%, respectively.[21]

Most bracket failures appear to occur within the first six months of treatment, aligning with findings from clinical trials by Choo et al and Hamilton et al.[22,23] However, this trend is not uniform across all bonding trials, as highlighted by House et al., who reported increasing bond failures over time in their study.[24] There is no clear link between the type of malocclusion and bond failures, and evidence regarding the relationship between extraction and non-extraction treatments and bond failures remains mixed and inconclusive.[23]

Influence of bonding procedure on bond failure

Moisture control with pharmacologic interventions

Contemporary orthodontic bonding materials, primarily composed of hydrophilic composite resins based on bisphenol A glycidyl methacrylate, necessitate a completely dry field for successful bonding.[25] Using an ant sialagogue like atropine sulfate for saliva control is thought to enhance bonding success. However, Ponduri et al found no significant difference in bond failure for brackets bonded with or without antisialagogue treatment in both anterior and posterior teeth.[26]

Pumicing of dental surfaces prior to bonding

The standard protocol for orthodontic bonding involves pumicing enamel surfaces to eliminate organic material such as the acquired pellicle. However, some studies suggest that skipping the pumicing step does not significantly impact bond failure rates, the significance of pumicing in removing plaque and debris is acknowledged.[27,28]

Especially with self-etching adhesives, pumicing seems essential, as higher failure rates were observed without it in studies by Burgess et al. and Lill et al.[29,30] This is partly due to the lower bond strength and sensitivity factors of self-etching protocols. Moreover, brackets bonded on non-pumiced surfaces often fail at the enamel-adhesive interface, and using fluoridated paste instead of non-fluoride pumice can detrimentally affect bond survival.[29,31]

Etching protocol

Enamel etching using 35-40% phosphoric acid for 30-60 seconds is a common practice. The trend towards self-etch bonding systems, which, as of 2008, were utilized by a third of orthodontists in the US, provides advantages like reduced chair time and less sensitivity to moisture.[32] A systematic review identified comparable risks of failure between self-etching and traditional acid-etching protocols,[33] with time-saving benefits despite the need for pumicing.[11]

Primer

Primers are used to penetrate the enamel surface deeply, enhancing bond effectiveness. Nandhra et al. found slightly higher bracket failures without a primer, indicating that primers contribute to stronger bonds.[34,35] Using a fluoride-containing sealant instead of a conventional primer showed no significant effect on bond failure but did not directly assess demineralization,[36]

Operator-coated verses precoated brackets

Precoated brackets, designed for bonding efficiency, show no significant difference in bond failures compared to operator-coated brackets.[11]

Indirect bonding

Indirect bonding entails positioning brackets on plaster models before transferring them to the mouth. Studies have shown no significant difference in short-term or one-year bond failure rates, indicating that indirect bonding does not adversely affect bond strength.[11]

Tooth whitening

The impact of bleaching products on enamel morphology and orthodontic bond strength is debatable. However, in-office whitening with 38% hydrogen peroxide gel significantly reduces bond survival.[11] The timing between bleaching and bonding is crucial, as immediate bonding post-bleaching increases failure risks. The majority of failures occur at the enamel-adhesive interface, likely due to enamel changes or oxygen release affecting resin polymerization.

Influence of orthodontic appliance on bond failure

Use of 0.018 inch verses. 0.022-inch brackets

The choice between 0.018 inch and 0.022 inch bracket slot systems is common in orthodontics, with each having its proponents. El-Angbawi conducted a randomized study involving 92 patients using either a 0.018 or a 0.022 inch preadjusted edgewise bracket system (both from 3M Unitek). The study found no significant difference in mean bracket failure per patient between the two sizes for either upper or lower arches, with differences of 0.20 and 0.34 brackets per patient, respectively, both with p values greater than 0.05.[37] Hence, no distinct clinical superiority of one system over the other was established, leaving the choice between them to individual preference.

Self-ligating brackets

Self-ligating brackets have gained popularity in recent years, with numerous studies evaluating their performance. However, bond strength comparisons with conventionally ligated brackets have not shown definitive differences. the performance in terms of bond strength can vary significantly depending on the type of bracket, whether it is self-ligating or conventional, and the specific brands and models being compared.[11]

Recycled brackets

Orthodontists frequently encounter bracket failures and seek to minimize them. Recycling debonded brackets is one strategy involving complete adhesive removal from the bracket base without damaging it. The reconditioning process involved washing in a non-acid solution, heating to 350°C for 24 hours, additional washing, electropolishing, and sterilization at 250°C.[11] A study reported no significant difference in failure rates between reconditioned and new brackets (7.1% and 5.8%, respectively), and both failed at the enamel-adhesive surface, indicating that reconditioning did not affect bond strength significantly.[38]

However, several factors must be considered when recycling brackets, including their integrity post-recycling, effects of multiple recycling phases, legal liabilities, and the need for sterilization to reduce cross-infection risk.[11] Therefore, further research is needed before integrating this practice into routine orthodontic care.

CONCLUSION

The comparative analysis of direct and indirect bonding methods, coupled with an evaluation of different adhesives, sheds light on the complexities of orthodontic bracket adhesion. The impact of patient-specific factors and tooth anatomy on bonding success is underscored. Furthermore, the exploration of recycled brackets opens new avenues for optimizing orthodontic treatment effectiveness.

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