Republic of Iraq
Ministry of Higher Education and Scientific
Research University of Baghdad
College of Dentistry

Bracket failure rate

A Project Submitted to
The College of Dentistry, University of Baghdad, Department of orthodontics in Partial Fulfillment for the Bachelor of Dental Surgery

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Baghdad Iraq May 2022

وَمَا تَوْفِيقِيٓ إِلَّا بِٱللَّهِ

Certification of the Supervisor

I certify that this project entitled " **bracket failure rate** " was prepared by the fifth-year student under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor’s name

Dedication

- ❖ I dedicated this project to my mother and father for their love and support for me in all difficult times
- ❖ to my sister (Ruaa Mahdi) to help me in this research
- ❖ to my best friend (Diyar Raad) to give me strength, persistence and support to continue my academic career with determination and help me to writing this research in best way and encouraged all time to persist.
- ❖ to (Gadeer Ali) also

They did not leave me in my difficult moments and continued to support me and give me positive.

I would like to thank every person from my family who helped me, whether with support with love or supplication.

Acknowledgment

Special thanks to our Dean, the Dean of the college of Dentistry, University of Baghdad, **Dr. Raghad AlHashimi**, for being so understanding and for upgrading the standards of our college.

I would like to express my gratitude to Assist Prof. **Dr. Yasser Abd-alkadum** the chair of Orthodontic department.

Then I would like to thank my supervisor, **Dr. Hadeel Adel** for her advice, care and support.

In the accomplishment of this project successfully, many people have best owned upon their blessing and the heart pledged support, this time I am utilizing to thank all the people who have been concerned with this project.

Last but not the least I would like to thank my classmates who have helped me.

List of abbreviations	
ARI	**Adhesive remnant index**
SEPs	**Self-etching primers**
MPa	**Megapascals**
Compomer	**Polyacid-modified resin composities**
RM-GIC	**Resin modified glass ionomer cement**
LED lump	**Light emitting diode**

Introduction

Orthodontics encompasses treatment modalities to correct dentoalveolar malocclusions and to restore dentofacial esthetics and function. One of the most accepted method to achieve these goals is the use of fixed appliances. In fixed appliance orthodontics, brackets are bonded to teeth surfaces to transform forces from archwires and other auxiliaries to the dentition **(Khan *et al,* 2022).**

One of the inevitable problems encountered in fixed orthodontics is bond failure. In good clinical practice, the failure rate of brackets should not exceed more than 6% **(Brown, 2009)**. But an incidence of 0.6-28.3% has been reported in a systematic review **(Almosa & Zafar, 2018)**. A bracket re-bonded due to failure can increase the treatment duration from 0.3 to 0.6 months **(Skidmore *et al.,* 2006; Stasinopoulos *et al.,* 2018)**, Bukhari *et al*. Reported that for every 6 months increase in treatment time, patient compliance to follow their appointments decreased by 23% **(Bukhari *et al.,* 2016)**.

Thus, the cost of treatment is enormously increased both for orthodontic practice and for the patient **(Brown, 2009)**. Multiple patient and operator-related factors affect the incidence of bond failure. Patient-related factors include preexisting enamel or dentine**,** defects, age **(Papageorgiou & Pandis, 2017; Barbosa *et al.,* 2018),** compliance to treatment **(Barbosa *et al.,* 2018)**, oral hygiene, jaw (maxilla or mandible), anterior or posterior teeth, overbite, and overjet **(Stasinopoulos *et al.,* 2018)**.

Operator-related factors like the pattern of etching, etchant concentration **(Wang *et al.,* 1994)**, type of primer **(Brown, 2009),** type of composite resin **(Paschos *et al,* 2019)** type of curing lamps **(Sfondrini *et al.,* 2001)**, curing time, bracket material **(Stasinopoulos et *al.,* 2018)**, and bleaching procedure carried out before orthodontic treatment can affect the bracket failure rate **(Sardarian *et al,* 2019)**.

Aim of the study:

Give an overview about bracket's bonding failure and the predisposing factors.

Chapter 1: Review of literature

1.1 Bonding of orthodontic appliance

From the inception of fixed appliance orthodontic treatment, brackets traditionally have been welded to gold or stainless steel bands. The band encompassed the tooth circumferentially, requiring the creation of interproximal space to accommodate the width of the band material.

This separation process, which was accomplished initially by placing wires and later elastomeries, was time-consuming for the orthodontist and uncomfortable for the patient. At the conclusion of treatment, these interproximal gaps had to be addressed again. In addition, banded appliances frequently caused gingival trauma when fitted, and decalcification under bands sometimes occurred during treatment. Therefore, the obvious solution to these problems was for the clinician to attach the brackets directly to tooth enamel, thus eliminating the need for bands **(Gange, 2015)**.

Bonding of attachments, eliminating the need for bands, was a dream for many years before rather abruptly becoming a routine clinical procedure in the 1980s. Bonding is paced on the mechanical locking of an adhesive to irregularities in the enamel surface of the tooth and to mechanical locks formed in the base of the orthodontics attachment. Successful bonding in orthodontics therefore requires careful attention to three components of the system: the tooth surface and its preparation, the design of the attachment base, and the bonding material itself **(David, 2013)**.

1.1.1 Bracket

They are used to deliver forces from the wires or other power modules to the teeth **(Soediono, 1989)**. Orthodontic brackets are important part of fixed appliances which are temporarily attached to the teeth during the course of orthodontic treatment **(Graber, 2016)**. There are an number of bracket designs available. Brackets can be classified in a number of ways (Table 1-1) **(Bhalajhi, 2012)**.

Table 1 classification of orthodontic brackets (Bhalajhi,2012):

Based on the technique: 1. Edgewise type of brackets. 2. Ribbon arch type of brackets. 3. Tip edge type of brackets.
Based on the mode of attachment to the tooth: 1. Weldable brackets. 2. Bendable brackets.
Based on the material of the bracket: 1. Metallic brackets (Stainless steel, titanium and cobalt chromium). 2. Ceramic brackets (Monocrystalline and Polycrystalline). 3. Plastic bracket.
Based on the mode of securing the archwire: 1. Self ligating brackets. 2. Brackets that need ligation.

1.1.2 Adhesives

Tooth movement can be achieved with the use of fixed appliances and is a result of the interaction between the bracket on the tooth surface and the arch wires, which are tied into each bracket, the brackets are attached directly to the tooth surface by means of an adhesive, light cured or chemically cured **(Brown, 2009)**.

The success of a fixed orthodontic appliance depends on the brackets being bonded to the teeth so that they do not fall off (debond) and protection against caries (decay) during treatment **(Mandall *et al.*, 2018)**.

Achieving high bond strength of orthodontic brackets to enamel, and hence a low failure rate, are the basic demands for orthodontic bracket bonding systems. Given that continuous replacements of loose brackets, are clinically inefficient, time-consuming, and costly. The search for an ideal orthodontic adhesive has been a hot topic for many years **(Alkadhimi & Motamedi, 2019)**.

Adhesion can be defined as the sum of the chemical and physical forces that represent the molecular attraction between materials in close contact. It expresses the resistance to separation forces **(Samantha *et al.*, 2017)**. An adhesive refers to the cement itself, while a bonding agent refers to the unfilled resin primer **(Alkadhimi & Motamedi, 2019)**.

Adhesion phenomena are critical in many clinical applications of dental materials, including orthodontic bonding. The success of the adhesion and success of orthodontic treatment is strictly linked to the characteristics of the interfacing surfaces and to the properties of the material used as bonding **(Samantha *et al.*, 2017)** and depends on the capability of the adhesive system to resist failure caused by many factors directed to the bracket-adhesive-enamel junction. These factors include stresses of mastication and stresses exerted by arch wires as well as other factors particular to the oral cavity, including humidity, rapid changes in temperature, and pH **(Mohammed *et al.*, 2016)**.

There are many properties that an ideal adhesive should possess, including an adequate bond strength-Orthodontic brackets are subjected to a large number of forces in the mouth resulting in a complex distribution of stresses within the adhesive and its junctions with the tooth surface and the bracket base **(Sunna,**

1998), so should be strong enough to avoid debond during treatment and weak enough to permit easy removal of brackets at debond without damage to the enamel surface and with the least discomfort to the patient. The clinically acceptable bond strength ranges from 5–8 MPa; **(Alkadhimi & Motamedi, 2019**).

A long working time, to facilitate command set with no drifting of the bracket; Easy to remove from the teeth/ brackets, to aid easy handling, fluoride releasing, to reduce the risk of enamel demineralization; **(Alkadhimi & Motamedi, 2019**).

Protect against dental caries (decay) ***(*Mandall *et al., 2018)***.

A long shelf life, where they can be stored for extended periods of time; **(Alkadhimi & Motamedi, 2019)**.

be available at a reasonable cost **(Mandall *et al.,* 2018)**.

Compatible with life and non-toxic i.e biocompatible **(Alkadhimi & Motamedi, 2019)**.

Adhesives currently available for bonding brackets to teeth are those with a resin/matrix composition, similar to 'white' filling materials (composites) and those supplied as a powder with liquid, or powder with water (glass ionomer cements), composites have been modified in recent years to form polyacid-modified resin composites (compomers), glass ionomers have been modified by adding a resin to form resin-modified glass ionomer cements, composites and glass ionomer cements may be set by a chemical reaction within the adhesive (chemical curing) or this may be triggered by shining a blue light onto the adhesive (light curing) **(Mandall *et al.,* 2018)**.

Bond strength of orthodontic composite is strongly influenced by molecular and structural mechanisms **(Condò *et al.,* 2021)**.

Choosing the right adhesive for bracket bonding is very important luting adhesive are recommended over filling adhesive for orthodontic bracket bonding. In composite resins different commercially available adhesives are present in the market. All manufacturers claim that their adhesive provides better bond strength over other companies products. While choosing a composite resin adhesive the orthodontist must remember that fixed braces are temporarily attached to teeth and bond strength of 5.9 to 8 MPa is clinically acceptable. A comparative study by Sharma concluded that commercially available adhesives have higher bond strength than minimum recommended limits **(Sharma, 2014)**.

Resin modified Glass ionomer cement (RM-GIC) is usually chosen for cases with amelogenesis and dentinogenesis imperfect as it is generally thought that it provide lower bond strength than composite resin but a systematic review showed that RM-GIC have the same clinical bracket failure rate as composite resin adhesives after 1 year **(Mickenautsch *et al.,* 2012)**.

The popularity of resin and resin hybrid materials is increasing because of their improved physical properties and low solubility in oral fluids. Though the newer cements, adhesive resins and hybrid cement resin combinations offer improved physical properties and clinical benefits, they also have some short comings. In orthodontics, polymeric adhesive resins are widely used as a dental bonding system to ensure an intimate and strong joint between the base of the bracket and the enamel surface **(Samantha *et al.,* 2017)**.

In the recent years greater emphasis have been given to patients comfort, appearance, function and hygiene. Newer orthodontic cements, adhesives and hybrid materials offer improved physical properties and clinical benefits. Selection of the right materials requires a proper understanding of the chemical properties and physical limitations **(Renuka, 2012)**.

One of the contributing factors of demineralization is the surface roughness caused by remaining adhesive around the brackets, which lead to plaque accumulation, so adhesive is commonly removed mechanically with some manoeuvres, as drilling or air abrasion, able to produce alterations in the roughness of the tooth surface, While complete removal of excess adhesive around the bracket is desirable, it can be a technique sensitive and time-consuming task **(Banerjee *et al.*, 2008)**.

Bracket failure during treatment is problem which increases operator chair side time and lengthens treatment time so bonding of orthodontic bracket to teeth is important to enable effective and efficient treatment with fixed appliance **(Mandall *et al.* 2018)**.

1.1.3 Techniques

1.1.3.1 Etching technique

Self-etching primers (SEPs) versus conventional etchants.

Acid etching of tooth surfaces to promote the bonding of orthodontic attachments to the enamel has been a routine procedure in orthodontic treatment since the 1980s, In order to attach an orthodontic device, such as a brace, to a tooth, the surface of the appropriate tooth first needs to be prepared so that it can retain the glue or bonding agent used to enable the device to be attached securely **(Hu *et al.* 2013)**.

The usual way of doing this has been to etch (roughen) the surface of the tooth with acid, commonly phosphoric acid, although maleic acid or poly acrylic acid are also sometimes used **(Grubisa *et al.* 2004)**.

Possible harms of etching include the permanent loss of enamel (hard surface) from the surface of the tooth making it more likely for it to lose calcium or weaken during and after treatment. Recently, to reduce the length of time and complexity of the process, a technique using self-etching primers (SEPs) has been developed as an alternative to conventional etchants or acids, SEPs combine conditioning and priming into a single treatment step which does not require acid etching **(Chu *et al.* 2011)**. These products save time and require less effort in clinical practice. However, there is always the concern as to whether they achieve the same level of bond strength as conventional products **(Alkadimi *et al.* 2019)**.

However, whether SEPs or conventional etchants are better, and the best SEP, acid, concentration and etching time, remain to be determined **(Hu *et al.* 2013)**.

Teeth cleaned with pumice powder or polishing paste to remove plaque pellicle (figure 1), then isolated the teeth to be ready for etching. Etchant applied to all tooth surfaces (figure 2), rubbed on each tooth using a microbrush (figure 3), left on teeth for 15-30 seconds, and rinse off thoroughly with water and spray whilst vacuuming to remove etchant (figure 4), after drying the teeth a white frosted chalky appearance is visible (figure 5). A primer is applied to every tooth covering the whole frosted area and be ready for bonding of the bracket (figure 6) **(Brown, 2009)**.

This procedure has some obvious disadvantages, First, an potential problem can be contamination by saliva or from a faulty air or water syringe tip after the enamel is prepared for resin bonding. Second, these multi procedural steps can be very time consuming **(Hu *et al.* 2013)**.

Figure 1: Pumicing teeth with a polishing pasteand pumice powder **(Soediono, 1989)**.

Figure 2: Etchant applied to teeth **(Brown, 2009)**.

Figure 3: Rubbed on each tooth using microbrush **(Brown, 2009)**.

Figure 4: Rinse the etchant by water to remove it **(Brown, 2009)**.

Figure 5: Frosty white enamel surface after drying the etched enamel surface **(Soediono, 1989)**.

Figure 6: Applying primer **(Brown, 2009)**.

1.1.3.2 Bonding technique

A-Direct technique

All teeth were cleaned with water and fluoride-free pumice for at least 30s and then dried with an oil-free air syringe. The enamel was then etched for 30s with 37% ortho-phosphoric acid, and the primer was applied with a small brush and spread with oil-free compressed air. The composite was applied on the bracket base, and the attachment was positioned on the tooth surface. Composite excess was removed with a probe before polymerization. The composite was polymerized with a LED lamp for 80s per bracket (20s for side: mesial, distal, occlusal and gingival) **(Menini *et al.* 2014)**.

B-Indirect technique

Indirect bonding technique involves a two-stage procedure.

- **First stage (laboratory stage):**

Models were cast on the same day as impression taking to ensure accurate fit of the transfer trays and trimmed so that they were no higher than 2cm, to allow easy use of the vacuum forming apparatus **(Thiyagarajah *et al.* 2006)**.

Quadrants to be indirectly bonded were marked with vertical and horizontal pencil lines on each tooth to identify long axes (figure 7) **(Andrews, 1976)**.

Figure 7: Referanc line on model **(Radha, 2014)**

The appropriate pre adjusted edgewise bracket was selected for each tooth. There is no need to place primer on the dental stone. Small amount of laboratory adhesive was placed onto the base of bracket in the same way as done in direct bonding or adhesive pre-coated brackets can be used (figure 8) **(Soediono, 1989).**

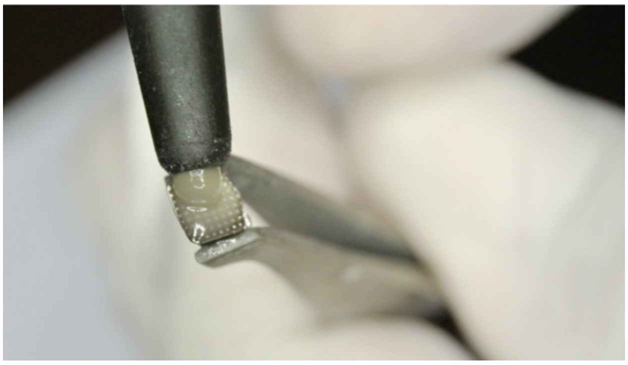

Figure 8: Adhesive is applied directly from the tube to the bracket base a thin layer of adhesive is usually used **(Soediono, 1989)**.

Then Each bracket was then positioned on its tooth (figure 9) and the adhesive was allowed to dry for at least 1 hour before the next step. A very thin coat of the water soluble separating media is then applied on the bonded brackets (figure 10). A thick coat will cause poor retention of the brackets in carrier tray **(Soediono, 1989)**

Figure 9: Bracket placed cured over the dental cast **(Soediono, 1989).**

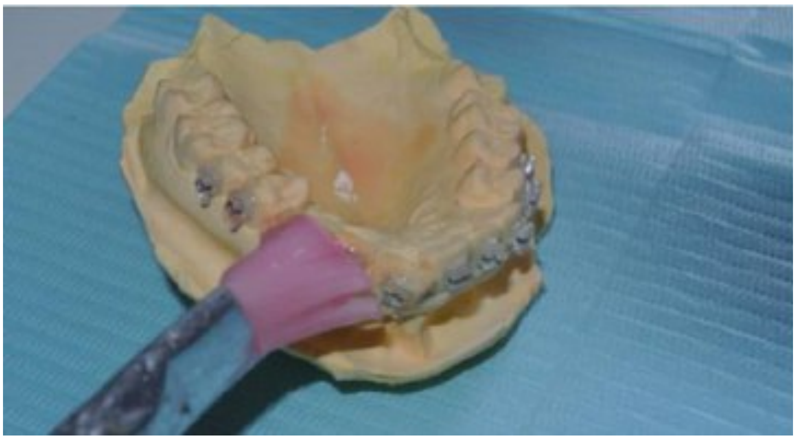

Figure 10: Separating medium applied over the brackets to avoid adhesion of brackets to soft silicon vacuum formed tray **(Soediono, 1989)**.

Trays were made using a 0.45 mm thick blank of transparent tray material. The transparency of the material allowed the use of light curing, which gave better control of working time. A circular blank was draped over a dry model and brackets **(Soediono, 1989)**.

The blank was first heated and then closely adapted to the model by means of negative pressure using a vacuum forming apparatus (Figure 11 & 12). After the transparent tray material had cooled it was trimmed with a hot instrument and removed from the model along with the brackets that were contained within it. Finally, the tray was trimmed close to the gingival margins of the teeth and two vertical slits were made from the edge of the tray to the mesial and distal gingival wings of each bracket in order to facilitate removal from the mouth, the teeth were prepared in similar was as explained in direct bonding technique **(Thiyagarajah *et al. 2006; Radha, 2014).***

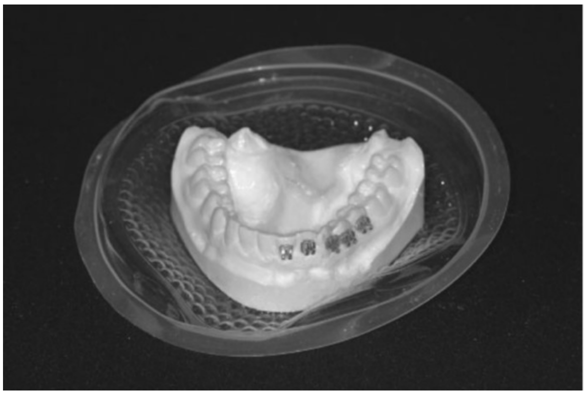

Figure 11: A tray blank adapted to a model **(Thiyagarajah et al, 2006)**

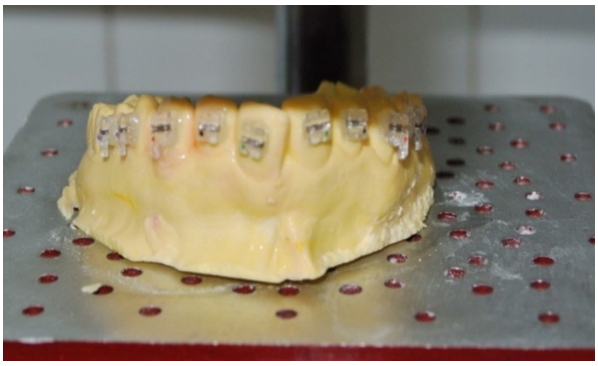

Figure 12: Model placed in a vacuum former **(Soediono, 1989)**.

When using indirect bonding, it is essential that the correct amount of adhesive is placed on the bracket bases before seating the tray, since subsequent removal of excessive set adhesive flash can prove difficult, especially with chemically-cured composites. Adhesive flash became less of a problem as the operator became more proficient in the technique **(Read, 1987)**.

Care must be taken to seat the tray properly and to apply even pressure over brackets when light curing. Otherwise, there is a danger that an uneven thickness of composite on a bracket base may weaken the bond and lead to bond failure at the time of tray removal **(Thiyagarajah *et al.* 2006)**.

- **Second stage (clinical stage)**:

the etching mask was placed over the cleaned facial surface of the appropriate teeth. The etchant was applied for 30s. The mask was removed, the teeth rinsed thoroughly for about 10s and then dried. A layer of primer was applied both on the etched surface and the bracket base inside the transfer tray, the trays were fitted in the mouth with even pressure (figure 13) to allow good adaptation of the brackets to the teeth and an even thickness of composite resin and light cured for 20s each on the buccal, distal, mesial and occlusal sides, for a total of 80s per bracket **(Migliau, 2017)**.

Brackets were cured starting with the most posterior tooth, then moving forwards and the transfer tray was then carefully removed using a probe or flat plastic instrument (Figure 14). Excessive adhesive flash was removed using a Mitchell's trimmer and rotary instruments if necessary **(Thiyagarajah *et al.* 2006)**.

Figure 13: Placement of a tray in the mouth **(Thiyagarajah et al. 2006)**.

Figure 14: Tray removal **(Thiyagarajah et al. 2006)**.

1.2 Bond failure

Orthodontic treatment involves the bonding of brackets to the tooth surface. These bonds should survive until the end of active treatment **(Moninuola *et al.*, 2010)**. A higher bond failure rate may pose a problem both for the patient and the orthodontist in terms of cost and longer treatment time and can therefore compromise orthodontic treatment **(Vasudevan *et al.*, 2021)**.

Ideally, a bonded bracket should remain attached to the tooth throughout treatment, the bond strength should be sufficient to resist tensile, shear, torque, and peel functional stresses. Bond failure is however encountered frequently in practice and may be due to numerous factors, Operator factor the clinicians manual dexterity, tooth factor i.e type of tooth and position of tooth in the arch, the type of etchant used and etching time, the adhesive used the bracket system and ligation forces used, the patient factor the masticatory forces and other factors related to the bonding system i.e variations in enamel surface **(Moninuola *et al.*, 2010)**.

Care in the clinical technique, moisture control, choice of bonding material and the appliance fitted, along with instructions given to the patient are all controlled by the operator, whereas the sex and age of the patient, the presenting malocclusion and care taken of the appliance are all patient factors. A better understanding of the reasons for orthodontic bond failure may lead to improved techniques leading to reduced failure rate **(Thiyagarajah *et al.*, 2006).**

1.2 Influence of bonding procedure on bond failure:

1.2.1.1 Moisture control with pharmacologic interventions:

Most orthodontic bonding materials in current use are hydrophilic composite resins based on the bisphenol a glycidyl methacrylate formula **(Mavropoulos *et al.*, 2003)** which requires a completely dry, operating field for successful bonding **(Bishara *et al.*, 1975).** Therefore pharmacologic control of salivary flow through premedication with an antisialagogue (atropine sulfate) is expected to enhance the success of bonding procedures. Interestingly, Ponduri *et al* **(Ponduri *et al*, 2007)** found no differences in the bond failure of brackets bonded with or without antisialagogue treatment for both anterior and posterior teeth.

1.2.1.2 Pumicing of dental surfaces prior to bonding:

Pumicing prophylaxis of the enamel surfaces prior to bonding is a standard step in the conventional bonding protocol to remove the organic material including the acquired pellicle. Some investigators have suggested that pumicing might be omitted from the bonding protocol, as no significant differences exist in bond failures or bond failure mode between pumiced and non-pumiced teeth **(Barry, 1995; Lindauer *et al.*, 1997; Shobbana Devi *et al.*, 2015)**.

The importance, however, of cleaning the tooth also lies in removing plaque and debris that might otherwise remain trapped at the enamel resin interface after bonding. Pumicing seems to be a necessary step, when bonding on enamel using a self-etching adhesive.

Both Burgess *et al* **(Burgess *et al.,* 2006)** and Lill. *et al* **(Lill *et al.,* 2008)** concluded that brackets bonded with a self-etching protocol on non-pumiced enamel surfaces were more likely to fail than those bonded on pumiced enamel surfaces. This might be in part due to the inherently lower bond strength of self-etching bonding protocols, as well as several sensitive factors specific for the self-etching technique, such as application time and air-dispersion time **(Miyazaki *et al.,* 2004)**.

Finally, based on the adhesive remnant index scores of failed brackets bonded on non-pumiced surfaces, the focus of bond failure was consistently at the enamel adhesive interface, as no adhesive remained on the enamel surface after bond failure **(Burgess *et al.,* 2006)**, this mode of failure may be related to the ability of the self-etching protocols to pretreat the enamel surface and allow adequate penetration into enamel Additionally, use of a fluoridated paste to clean the enamel surface prior to bonding, instead of conventional non-fluoride pumice, seems to have a detrimental effect on survival of precoated brackets bonded with a self-etching protocol.

1.2.1.3 Etching protocol:

Etching the enamel surface is a critical variable that affects bond strength and bond failure location. Factors that influence acid etching of enamel include type of acid etch, concentration of acid etch, and etching time **(Barkmeier, 2009)**.

Etching of enamel surfaces prior to bonding with phosphoric acid is a widely used technique, with the most common protocol being the use of 40% phosphoric acid for about 60s. However, several reports have indicated that acid with reduced concentration might also be adequate. Carstensen 1993 **(Carstensen, 1993)**, compared the use of 37% phosphoric acid with 2% phosphoric acid for the bonding of brackets to anterior teeth and found no statistically significant difference in failures rates between the two protocols.

Additionally, the results of the adhesive remnant index score indicated that the application of 37% phosphoric acid resulted in significantly more residual adhesive left on the teeth compared to the 2% phosphoric acid concentration **(Mengqin, 2018)**.

The authors concluded that etching with 2% phosphoric acid seems to reduce the depth of acid penetration into deeper enamel layers and the total loss of superficial enamel, which is especially rich in fluoride. However, the results of this trial should be viewed with caution as the experimental design of the trial was unclear, the sample size was small, and only anterior teeth were included **(Fleming *et al.,* 2012)**.

There has been constant interest in recent years about the omission of etching as a separate step, by adopting a one-step bonding procedure and thereby simplifying/shortening bonding time. The so-called self-etch bonding systems or self-etch primers as of 2008 were routinely used by one-third of orthodontists in the United States **(Keim *et al.,* 2020)**.

The proposed advantages of self-etching primers include reduced chair-side time, (although, as stated earlier, this is somewhat tempered by the requirement for judicious pumicing before bonding to minimize the risk of failure), reduced sensitivity to moisture, and reduced inventory requirements. In a recent systematic review, which included five high-quality randomized trials **(Fleming *et al.,* 2012)**, the risk of failure was comparable between self-etching and conventional acid-etching protocols (5.9% vs. 4.5%, respectively).

Additionally, the authors of the review reported that, assuming full-mouth bonding of 28 teeth, the self-etching protocol was associated with an average time-saving of 10.8 min per patient compared to conventional protocols. However, none of the included studies reported on chair time needed for tooth prophylaxis, which is crucial for effective bonding with self-etching protocols.

Therefore the necessity for pumicing with these technique-sensitive applications might eventually outweigh the shorter duration of bonding associated with the combination of etching and primer in one step and the elimination of the need for rinsing **(Pandis & Eliades, 2005)**.

According to the (SEPs) versus conventional etchants as mention above in the technique, it showed by Namdari and other authors that there was no difference between the self-etch primer and conventional etch/primer in bracket debonding at a medium level of evidence, However, there was statistically significant reduction in clinical bonding time using self-etch primer **(Namdari *et al.*, 2021)**.

From January 2008 the practice bonding material and technique changed from the self- etching primer technique to conventional acid etch, in the hope that this would reduce the number of debonded brackets **(Brown, 2009)**.

It showed by Fleming and other authors that there is weak evidence indicating higher odds of failure with self-etch primer than acid etch over 12 months in orthodontic patients, and there is strong evidence that a self-etch primer is likely to result in a modest time savings (8 minutes for full bonding) compared with acid etch **(Fleming *et al.*, 2012)**.

1.2.2 Bracket failure rate in orthodontic patients bonded with and without primer:

Primer versus non-primer bonding. Primer may be used as part of the bonding process and with light-cured composite; it is usually unfilled resin. Primers has been introduced to routine bonding procedures for orthodontic fixed appliance for two purpose **(Rai, 2015)**:

The primary purpose is enamel surface penetration to improve the effectiveness of the final bond. and it's secondary purpose in orthodontic bonding includes enhancing the bond strength and some researchers claimed that it protect the enamel from the consequent demineralization by the acid-etching and to reduce marginal leakage **(Rai, 2015)**.

If a primer could be avoided during bonding brackets, this would represent a financial saving and a potential time saving by missing a step in the bonding process **(Alkadhimi & Motamedi, 2019)**.

Bonding without the use of primer has been a subject of much interest to the orthodontist because it might be possible to reduce the risk of occupational exposure to primer and its unpolymerized components. It has been showed by Rai that bonding with primers show less bracket failure rate in comparisons to non-primer bonding. However, this difference in not statistically significant norclinically **(Rai, 2015)**.

Nandhra et al. performed a randomized trial on the use or omission of a primer when bonding precoated brackets with a two-stage etch-and-prime protocol. They found that bonding without use of a primer was associated with slightly higher bracket failures compared to conventional bonding with a primer. Additionally, bond failures were more likely to occur at the adhesive enamel interface when no primer was used **(Nandhra *et al.,* 2014)**.

This implies that orthodontic bonding with no primer has lower bond strength than orthodontic bonding with a primer and seems reasonable, since primers can penetrate at a higher rate and considerably deeper into the enamel following acid etching **(Eliades, 2014)**.

Sealing of the enamel surface with a resin of thinner viscosity may present a benefit in protecting the enamel surface from subsurface lesions due to leakage and demineralization **(Ghiz *et al.,* 2009; Papageorgiou and Pandis, 2017)**.

Finally, substitution of the conventional primer with a fluoride-containing sealant has been suggested as a means of preventing demineralization around the bracket through fluoride fortification. Varlik and Demirbas found no statistically significant effect on bond failure with the use of the fluoride-containing sealant compared to a conventional primer.

However, demineralization during treatment was not directly assessed. Therefore these results should be viewed with caution due to existing methodological issues and the small sample size of this trial **(Varlik & Demirbaş, 2009)**.

1.2.3 Bonding methods:

Bonding of orthodontic attachments to tooth can be accomplished either through direct or indirect methods. The advent of direct bonding procedure and the light cure resins have given the operator an unlimited working time and ease of work in minimizing errors during bonding. Direct bonding is still more preferred procedure than indirect bonding by most of the operators. However, achieving an accurate and consistent bracket positioning for the posterior continues to pose a problem because of inaccessibility. A significantly superior, efficient and effective indirect bonding methods has been developed, which has improved accuracy and reduced chair side time for both patient and the operator over the last three decades **(Sondhi, 1999; Koo *et al.,* 1999; Moshiri & Hayward, 1979; Vijayakumar *et al.,* 2014)**.

In addition to being a highly sensitive technique, indirect bonding has two significant disadvantages. First, the occluso-gingival insertion of the transfer tray causes the adhesive coated brackets to scrape along the tooth surface resulting in uneven distribution, rather than perpendicular placement. Second, when opaque trays were used the putty covering the palatal side prevent the light from entering the palatal and occlusal aspect during curing **(Husain *et al.,* 2009)**.

Many studies have been conducted in order to test the indirect technique effectiveness. In fact, only few reports evaluated the clinical reliability of the indirect bonding technique compared with the conventional bonding technique **(Menini *et al.,* 2014)**.

It showed by Anna Menini and other authors that no significant differences were found between direct and indirect bonding, generally direct and indirect bonding techniques have no effect on bonding failure rate, however there is no differences in the upper jaws were found between two techniques, while a significantly greater number of detachment occurred in the lower arch (direct or indirect) **(Menini *et al.,* 2014)**.

The bonding of orthodontic brackets and their failure rates by both direct and in-direct procedures are well-documented in orthodontic literature. Over the years different adhesive materials and various indirect bonding transfer procedures have been compared and evaluated for bond failure rates **(Vijayakumar *et al.,* 2014)**.

Bond failure rates were assessed by Vijayakumar and other authors for over-all direct and indirect procedures, anterior and posterior arches, and for individual tooth, it showed that the over-all bond failure was more for direct bonding. Anterior bracket failure was more in direct bonding than indirect procedure, which showed more posterior bracket failures. In individual tooth bond failure, mandibular incisor, and premolar brackets showed more failure, followed by maxillary premolars and canines **(Vijayakumar *et al.,* 2014)**.

Two identified randomized trials compared the bond failures for direct and indirect bonding protocols. The first trial assessed the short-term (3 months) bond failure with the two protocols, using a chemically-cured composite resin, and found no statistically significant difference between them **(Aguirre *et al.,* 1982; Thiyagarajah *et al.,* 2006)**.

The second trial, assessed the one-year bond failure using a light-cured composite resin and likewise found no statistically significant difference between indirect and direct bonding. Therefore existing evidence does not support the notion that indirect bonding of brackets might have a detrimental effect on bond strength The site of bond failure with regards to tooth type does not vary between the two techniques **(Thiyagarajah *et al.,* 2006)**.

1.2.4 Bracket base design:

Numerous studies have been made of the variables which influence bond strength, including the adequacy of the acid etch technique, the particular resin bonding agent employed, the nature of the force system applied to the bond interface, and the bracket base design. The base component of orthodontic brackets makes possible the attachment of a bracket to the tooth. This attachment must be strong enough to transfer orthodontic forces from the wires to the teeth, withstand masticatory loads and should easily be removed at the end of treatment **(Soediono, 1989)**.

Orthodontic brackets are attached to teeth or other supporting structures of porcelain, metal, composite and acrylic through various commercially available adhesives. To increase retention of bracket bases to adhesives various chemical, mechanical or combination of both retention designs have been added to the bracket base **(Soediono, 1989)**.

The ceramic bases, like the metal bases, achieve bonding to the resin through mechanical interlocking but are bulky and may be brittle. The metal bracket base has proved to be most reliable and has been most used. However, as discussed previously, the bond strength may be greatly influenced by the bracket base design. As the retentive area of bracket bases has been reduced for esthetic reasons, the importance of variables such as weld spots, mesh wire size, and retentive volume has become more evident. The foil mesh type of base has been most widely used and provide adequate bond strengths in tension and shear **(Reynolds & von Fraunhofer, 1967; Faust *et al.,* 1978; Lopez ,1980)**.

However, most studies demonstrate that the bond failure in such an enamel-bonded bracket occurs at the resin-mesh interface because of stress concentrations and defects in the resin film, bond strength of mesh bases may also be reduced by corrosion following leakage at the resin-mesh interface **(Maijer & Smith, 1982**).

1.2.5 Failure pattern of different bonding systems (Light cured and chemically cured):

Composite resins with different polymerization mechanisms such as chemical, light, or dual curing are the most frequently used adhesives in orthodontic bonding **(Klocke *et al.*, 2003)** Although composite resins. provide sufficient bonding strength and are easy to handle, they adhere to the tooth enamel only by micro retention, requiring a dry field **(Mohammed *et al.*, 2016)**, the use of light-cured composite resins. In dentistry has grown rapidly in the last decades as an improvement over chemically-cured autopolymerizing resins **(Oesterle *et al.*, 2002)** as they are easy to use, versatile, and have extended working time **(Tavas & Watts, 1979)**.

Consequently, light-curing allows sufficient time for, careful bracket placement the ease of cleanup around the bracket base before bonding, and consistent handling properties, and, by virtue of command set, permits seamless engagement of arch wires. One of the earlier existing randomized trials comparing chemically-cured and light cured composite resins for bonding metal brackets **(Trimpeneers & Dermaut, 1996)** reported that the light cured composite resin was associated with twice the bond failure rate of the chemically-cured resin.

However, the authors had compared a fluoride-releasing light-cured composite resin to a conventional chemically-cured composite resin in this trial, and as a result reported significantly higher overall bond failure rates (18.4%) than the average bond failure rates found in the literature (around 10%).

A subsequent trial comparing chemically-cured and light-cured composite resins used to bond metal brackets found no statistically significant difference in the bond failure rates **(Sunna & Rock, 1998)**.

Finally, a third randomized trial comparing chemically cured and light-cured composite resins used to bond polycrystalline ceramic brackets found no significant differences in both the bond failure rate and the bond failure mode, as assessed with the ARI score **(Årtun, 1997)**.

This has led to the wide acceptance in the last decade of light-cured composite resins for orthodontic bonding over chemically-cured adhesives **(Keim *et al.*, 2020)**.

1.2.6 Failure pattern of different bracket system (metallic and ceramic brackets):

Most of the orthodontic brackets are made of stainless steal because it provide optimum properties required for an orthodontic bracket **(Soediono, 1989)**.

stainless steel brackets are most commonly used at the orthodontic office due to their low cost, high corrosion resistance in the mouth, higher modulus of elasticity, and excellent biomechanical properties **(Keim et al, 2008; Oh *et al.* 2005)**.

Since stainless steel cannot bond chemically with orthodontic adhesives, these brackets have different types of gauge mesh bases for increasing the contact area with the adhesive during bracket positioning, mesh eyelets are filled with orthodontic adhesive, and the subsequent polymerization creates a micromechanical bond between the bracket and the adhesives **(Gange, 2015)**.

In addition to numerous advantages, stainless steel brackets also have some drawbacks, which are poor aesthetics and low biocompatibility. Both clinicians and patients are aware of this problem, which leads to increased interest in ceramic brackets due to their cosmetic properties, as ceramic brackets are transparent or translucent they mask the appearance of fix orthodontic appliances **(Soediono, 1989)**, and high biocompatibility **(Oh *et al.* 2005)**.

However, ceramic materials, just like stainless steel, do not form chemical compounds with acrylic and diacrylate orthodontic adhesives **(Swartz M, 1988)**.

Bases of ceramic brackets are usually formed with recesses or covered with additional ceramic particles to ensure a better mechanical interlock to the adhesive. Another method is to coat the ceramic base with silane to provide chemical adhesion **(Bishara *et al.* 1997; Russell, 2005)**. It showed by the Ogiński and other authors that the failure rate of the metal brackets was seven-times higher than that of the ceramic brackets and this difference was statistically significant **(Ogiński *et al.* 2020)**.

These results are in agreement with the study by Hitmi *et al*, who compared the detachment rates of the metal, plastic, and ceramic brackets bonded with resin-modified glass- ionomer adhesive and, similarly to our stud, discovered a statistically larger percentage of failures of metal brackets than ceramic ones **(Hitmi *et al.* 2001)**.

The failure rate of the metal brackets is reported to be much higher during the first 6 months of the treatment **(Sunna *et al.* 1998; Campoy *et al.* 2010; Hammad *et al.*, 2013; Dominguez *et al.* 2013)**.

Chapter 2: Discussion

The bracket failure rate is the one of the most common clinical problems in orthodontic treatment that the orthodontist encountered. The duration of the treatment course, make the major concern to the patients. Bracket failure means longer treatment time for the patient, parent, who has to take additional time from their normal schedule to attend appointments, inevitably compromises treatment time/results, as it will not only lengthens the treatment time but damages the enamel due to repeated bonding procedure. Bracket failure was found to significantly affect treatment duration, with an extra 0.6 month for each additional bracket failure, excessive bracket failure alone might lead to prolonged treatment by 1.8 months **(Stasinopoulos, 2018)**.

Success of orthodontic treatment is strictly linked to the characteristics of the interfacing surfaces and to the properties of the material used as bonding **(Samantha *et al.*, 2017)**.

Orthodontic adhesive system is able to generate, influences the outcome of the bracket bonding to the surface of the dental enamel, choosing proper bonding material is important to reduce the rate of bracket failure. There was no significant difference in the failure pattern for brackets bonded with either compomer or resin adhesive and there was no significant difference in first failure time distribution for brackets bonded with either compomer or a no-mix resin adhesive **(Millett, 2000)**.

Many studies proven that the bonding method either by direct or indirect also is factors that generally do not effect on the bonding failure rate. Two identified randomized trials compared the bond failures for direct and indirect bonding protocols, both found no statistically significant difference between indirect and direct bonding, generally direct and indirect bonding techniques have no effect on bonding failure rate **(Menini *et al.*, 2014)** but one study is showed that overall bond failure was more for direct bonding **(Vijayakumar *et al.*, 2014)**.

Acid etching of tooth surfaces to promote the bonding of orthodontic attachments is another factors that the researchers differed about the possibility of its affect on the failure rate of the bracket, some studies showed no difference between the self- etch primer and conventional etch/primer in bracket deboning at a medium level of evidence, However, there was statistically significant reduction in clinical bonding time using self-etch primer **(Namdari *et al.,* 2021)**.

Another study has showed that is weak evidence indicating higher odds of failure with self-etch primer than acid etch over 12 months in orthodontic patients, and there is strong evidence that a self-etch primer is likely to result in a modest time savings (8 minutes for full bonding) compared with acid etch. The primer is important step for bonding of the bracket to tooth surface through enamel penetration and increase the bond strength to enhanced the final bond, this implies that orthodontic bonding with no primer has lower bond strength than orthodontic bonding with a primer **(Ghiz *et al.,* 2009; Papageorgiou & Pandis, 2017)**.

Another study showed bonding with primers has less bracket failure rate in comparisons to non-primer bonding. However, this difference in not statistically significant nor clinically **(Rai, 2015)**.

Chapter 3: conclusion

Bracket to tooth bonding is crucial for effective successful short duration treatment. Bonding needs to be strong enough to withstand masticatory and orthodontic forces and at the same time when detached at a reposition step or at the end of treatment it needs to cause no harm to the tooth surface. High bond failure rate not only increase the chair side time but also result in increasing the treatment duration. This matter is of concern to the researchers for many years, yet there is not a one protocol to follow to have the least bonding failure rate.

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