

A COMPARISON OF SHEAR BOND STRENGTH OF DENTURE TEETH TO DENTURE BASE USING DIFFERENT MEANS OF RETENTION: IN VITRO PILOT STUDY

Dima Taha El Baba¹ | Paul Boulos²

Objectives: The objective of this work is to evaluate the shear bond strength between denture base resin and three different acrylic artificial denture teeth. The latter was subjected to three different surface modifications on the ridge lap area and compared to unmodified acrylic artificial denture teeth.

Methods: In this experimental in vitro study, twenty-four maxillary central incisor acrylic teeth were used from each of three manufacturers; namely Major®, Ivoclar® and Myerson®. The teeth were additionally divided into four test groups with six specimens in each: a control group, a chemical retention group, a mechanical retention group, and a mechanical plus chemical retention group. The teeth in each group, with the exception of the control group; are subjected to one of the four different surface modifications prior to packing of the denture base resin. Seventy-two acrylic resin test blocks thus obtained are submitted to 5,000 cycles of thermocycling between 5 and 55°C for 30 seconds in each water bath and 10 seconds in between. The resins are subsequently tested for shear bond strength between the acrylic resin teeth and the denture base resin in the Universal Testing Machine using the strength mode. The compression load is applied through a roll pin at a crosshead speed of 1mm/min and at an angle of 45 degrees (relative to the long axis of the tooth). Anova, Kolmogorov-Smirnov, Kruskal Wallis and Post hoc tests were used for statistical data analysis. The significance level retained corresponds to a p-value ≤ 0.05 .

Results: The multilayer teeth of the nano hybrid composite, "Ivoclar®" had the highest bonding strength in the control and chemical bonding groups. For the mechanical or mechanical plus chemical retention groups, no significant difference between the 3 types of teeth was observed.

Conclusions: The multilayer nanohybrid "Ivoclar®" teeth are the most retentive teeth to the denture base. If resin teeth are desirable, applying combined retentive measures would be recommended.

Keywords: Resin, Dental Retention, Chemical Processes, Mechanical Phenomena, Shear bond strength.

Corresponding author:

Dima Taha El Baba, e-mail: dimababa@hotmail.com

Conflicts of interest:

The authors declare no conflicts of interest.

1. Graduate student, Postgrad student of Department of Esthetic and Restorative Dentistry, Saint Joseph University of Beirut, Beirut, Lebanon

2. Professor, Department of Removable Denture, Saint Joseph University of Beirut, Beirut, Lebanon

COMPARAISON DE LA RÉSISTANCE AU CISAILLEMENT DES DENTS DE PROTHÈSE À LA BASE DE LA PROTHÈSE À L'AIDE DE DIFFÉRENTS MOYENS DE RÉTENTION : ÉTUDE PILOTE IN VITRO

Objectifs: L'objectif de ce travail est d'évaluer la résistance au cisaillement entre la résine des bases prothétiques et trois types différents de dents prothétiques en résine acrylique. Ces dernières ont été soumises à trois modifications de surface différentes au niveau de la zone palatine et comparées à des dents en résine acrylique non modifiées.

Méthodes: Dans cette étude expérimentale in vitro, vingt-quatre dents maxillaires centrales en résine acrylique de différents fabricants — Major®, Ivoclar® et Myerson® — ont été utilisées. Les dents ont été divisées en quatre groupes de test, comprenant chacun six spécimens : un groupe témoin, un groupe à rétention chimique, un groupe à rétention mécanique et un groupe à rétention mécanique plus chimique. Les dents de chaque groupe, à l'exception du groupe témoin, ont été soumises à l'une des quatre modifications de surface avant le montage de la résine de base prothétique. Les soixante-douze blocs de résine ainsi obtenus ont été soumis à 5 000 cycles de thermocyclage entre 5 et 55 °C pendant 30 secondes dans chaque bain d'eau et 10 secondes entre les bains. Les échantillons ont ensuite été testés pour la résistance au cisaillement entre les dents en résine acrylique et la résine de base prothétique à l'aide de la "Universal Testing Machine". La charge de compression a été appliquée au moyen d'une tige cylindrique à une vitesse de 1 mm/min et selon un angle de 45° par rapport à l'axe longitudinal de la dent. L'analyse statistique a été effectuée à l'aide des tests Anova, Kolmogorov-Smirnov, Kruskal-Wallis et Post hoc. Le seuil de signification retenu correspond à une valeur de $p \leq 0,05$.

Résultats: Les dents multicouches en composite nanohybride « Ivoclar® » ont montré la résistance de liaison la plus élevée dans les groupes témoin et à liaison chimique. Pour les groupes à rétention mécanique ou mécanique plus chimique, aucune différence significative entre les trois types de dents n'a été observée.

Conclusions: Les dents multicouches nanohybrides « Ivoclar® » sont les plus rétentes vis-à-vis de la résine de base prothétique. Si des dents en résine sont utilisées, il est recommandé d'appliquer des moyens de rétention combinés.

Mots-clés: Résine, Rétention dentaire, Processus chimiques, Phénomènes mécaniques, Résistance au cisaillement.

Introduction

Acrylic resin has become the material of choice for production dental prostheses due to the lack of raw material for vulcanite after World War II. It has been available as a denture base material for over 60 years [1]. New materials with superior properties have been introduced in recent years. However, acrylic resin remains the most popular choice among dentists due to its advantages, such as simple processing technique, low manufacturing cost, easy repair and good aesthetic properties [2, 3].

It is mainly the elderly who seek dental treatment requiring a dental prosthesis to replace missing teeth: partial or total and removable or fixed on an implant [4]. However, detachment of the teeth from the acrylic base of the prosthesis remains a problem for patients and clinicians. The failure rate of acrylic dentures resulting from fracture has been reported to be unacceptably high, with the most common type of failure documented being tooth failure or fractures [3-5]. According to the literature approximately 30% of all denture repairs performed by commercial dental laboratories involved defects attributed to the failure of the bond between the teeth and the base resin of the denture especially in the anterior region [3-6, 7]]. A study by Real-Osuna shows that 13, 7% of implant-supported hybrid prostheses complications are fractures of prosthetic teeth [8]. This detachment can be attributed to less contact area for bonding and the direction of stress encountered during function [7-9]. Variables such as tooth position/alveolar ridge, occlusion, treatment, different denture base materials, and preparation of ridge coverage of tooth surfaces are also factors that can affect the bond between the base materials of the prosthesis and the acrylic teeth. Proper bonding between the base resin and the teeth is necessary as it increases

the strength and durability of the prosthesis since the teeth are an integral part of the prosthesis [5]. Acrylic resin artificial teeth are often preferred because they chemically bond to the denture base materials and are easier to fit. The combination of acrylic teeth and acrylic denture base is mediated by polymethyl methacrylate (PMMA) which is copolymerized with a cross-linking substance. To reduce the fracture of acrylic teeth, a cross-linking substance is used in a high proportion [10]. Several factors affect the bonding. Key among them are wax remaining on the tooth ridge overlapping area, careless application of sealant during processing, insufficient use of monomer during processing, and the method of curing used in the process treatment of the denture base resin [3-11].

Most attempts have involved chemical treatment or mechanical retentive modifications to improve the bond strength between the resin teeth and the acrylic base. Contradictory results have emerged with the use of monomer, the reduction of the glazed surface of the tooth or the placement of a groove to improve the retention between the artificial teeth and denture base [13].

Several studies have been performed to assess the benefit of one or the other (chemical or mechanical retentive means), but none have studied the combination of the two retention means.

The objective of this study is to evaluate the bonding strength between different types of artificial teeth and the acrylic base of a prosthesis with various retentive means used individually or combined.

The null hypotheses state that there are no significant retention differences between the teeth and the resin denture base when comparing different retentive products and different artificial teeth.

Materials and methods

In this experimental pilot in vitro study, participants provided their informed consent after the study was authorized by the Saint Joseph University ethical committee (reference: CER – 2025 -218).72 maxillary central incisor acrylic teeth were used: 24 Major® classic acrylic resin teeth (Major Prodotti Dentari S.P.A. Moncalieri (TO), Italy), 24 Ivoclar® composite resin teeth (Phonaresll Ivoclar Vivadent AG- Schaan, Liechtenstein) and 24 Myerson® Special ceramics teeth (Myerson LLC, Chicago, IL U.S.A.). The investigation was carried out with a single investigator. Differential surface treatment was done at the ridge lap area. 12 groups, each of which included 6 specimens, were then created and classified as follows: group A all specimens were made with Major® teeth without any retention; group B: all specimens were made with Major® teeth with chemical retention; group C: all specimens were made with Major® teeth with mechanical retention made with a special « Steel Groove Cutter 108 » Meisinger, Ivoclar®; and group D: all specimens were made with teeth in Major® with double mechanical and chemical retention. Groups E, F, G and H, all specimens were treated as for groups A, B, C and D respectively, but including Phonaresll Ivoclar® teeth. And groups I, J, K and L specimens were treated as for groups A, B, C and D respectively, but including Myerson® Special teeth.

For all groups, a central incisor was used with a similar mold for the three different brands of teeth in order to standardize the tooth/resin contact surface. Consequently, the same dimensions (8mm in length, 7mm in width and 1.5mm in depth) of the bases of the teeth at the collar were adopted. The central incisor was placed at a 45-degree angle with the horizontal using a protractor.

For teeth that receive mechanical retention, grooves were created in

the base before flask placement with a special bur "Steel Groove Cutter 108" Meisinger, Ivoclar -Vivadent AG- Schaan, Liechtenstein.

For teeth that receive chemical retention, a layer of "Visio .link" PMMA & composite primer from "Bredent group - Senden - Germany", a polymethyl-methacrylate primer, was applied to the base after the wax was removed. The teeth were thoroughly cleaned with alcohol to remove any debris and photopolymerized for 90 seconds with visible light (wavelength between 370 and 400 nm). A matte finish is indicative of a good application of the primer.

The main resin base used is Vertex Castavaria (3D systems, Soesterberg, The Netherlands), it is a heat and pressure-assisted self-polymerizing acrylic.

The experiment was carried out in the Craniofacial Research Laboratory at Saint Joseph University in Beirut. All samples underwent 5000 cycles of thermocycling (Thermocycler, SD Mechatronik - GMBH, Feldkirchen-Westerham, Germany): each cycle consist of 30 seconds in 5°C water bath then 10 seconds break and then 30 seconds in 55°C water bath, which represented 6 months of

intraoral usage [14]. The samples were then mounted on the universal machine, YLE Universal Testing Machine – strength mode (YLE Universal Testing Machine, YLE GmbH, Finland), to perform the shear test with a compression load at an angle of 45 degrees (relative to the long axis of the tooth) at the level of the middle third of the palatal surface of the anterior teeth until fracture (Figure 1). The compressive load is applied through a roll pin at a crosshead speed of 1mm/min. The loading rate is extremely important when testing as it could influence the results.

Statistical analysis

IBM SPSS Statistics (Chicago, IL, USA, version 25.0) statistical software was used to analyze the data. The significance level retained corresponds to a p -value ≤ 0.05 .

The Kolmogorov-Smirnov test was used to shear strength variable's normality distribution. ANOVA test was used to assess if there is a significant difference between the three types of teeth and between the types of retention. Kruskal Wallis test was used when the distribution was not normal. And Post hoc analysis

was performed using Tukey's test to confirm where differences occurred and between which groups.

Results

A total of 72 samples were included in the study: 24 Major®, 24 Myerson® and 24 Ivoclar®. The shear bond strength of acrylic resin to denture teeth is depicted in Figure 2.

Type of teeth

This study showed that the resistance to shear forces of Major® and Myerson® teeth follows a normal distribution (p -value <0.05), thus justifying the use of a parametric statistical test.

The ANOVA study (Table 1) showed that there is a significant difference in the mean shear force between the Major® teeth groups ($F(3.20) = 3.686$, P value = $0.029 < 0.05$). A post hoc test by Tukey revealed that the shear strength was statistically significantly lower in the "control" group (211.33 ± 70.681 (N), P value = $0.014 < 0.05$) compared to the "chemical + mechanical" group (378.83 ± 136.618 (N)).

Additionally, shear strength was statistically lower in the "chemical" group (211.67 ± 82.988 (N),



Figure 1. Sample in the universal testing machine.

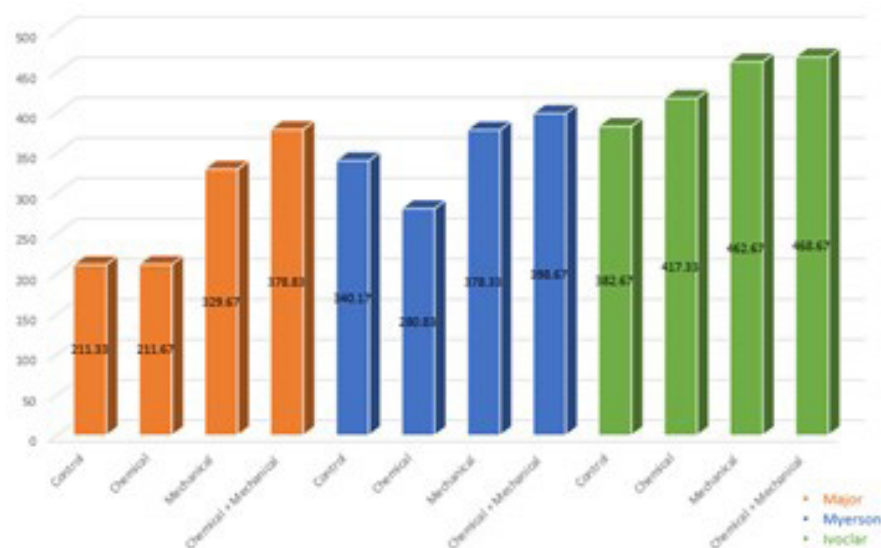


Figure 2. Results of shear bond strength of all the specimens in Newton.

P-value = $0.015 < 0.05$) compared to the “chemical + mechanical” group of Major® teeth (378.83 ± 136.618 (N)).

No significant difference was observed between the groups using the one-way ANOVA test ($F(3, 20) = 2.181$, P-value = $0.122 > 0.05$) of the Myerson® teeth (Table 1).

This study showed that the resistance to shear forces does not follow a normal distribution of the Ivoclar® teeth, thus justifying using a parametric statistical test. No significant difference was revealed between the groups using the Kruskal Wallis test (P-value = $0.749 > 0.05$) (Table 2).

Retention Type

This study showed that the resistance to shear forces of all control and chemical groups follows a normal distribution ($p\text{-value} < 0.05$), thus justifying using of a parametric statistical test.

A statistical difference was revealed between the groups determined by one-way ANOVA ($F(2, 15) = 4.122$, P-value = $0.037 < 0.05$) (Table 3). Tukey post hoc test revealed that the shear force is statistically lower in the “Major®” type (211.33 ± 70.681 (N)), P-value = $0.037 < 0.05$) compared to the “Ivoclar®” type (382.67 ± 144.993 (N)).

A statistical difference was revealed between the chemical groups determined by one-way ANOVA ($F(2, 15) = 5.737$, P-value = $0.014 < 0.05$) (Table 3). Tukey post hoc test revealed that the shear force is statistically lower in the “Major®” type (211.67 ± 82.988 (N)), P-value = $0.012 < 0.05$) compared to the “Ivoclar®” type (417.33 ± 145.661 (N)).

This study showed that the resistance to shear forces of all mechanical and chemical + mechanical groups does not follow a normal distribution, thus justifying using a parametric statistical test.

No significant difference was measured between the mechanical groups using the Kruskal Wallis test (P-value = $0.087 > 0.05$) (Table 4).

Table 1. ANOVA test of Major and Myerson teeth

		Sum of Squares	Df	Mean Square	F	P-value
Major	Between Groups	129517.79	3	43172.6	3.686	0.029*
	Within Groups	234258.83	20	11712.94		
	Total	363776.63	23			
Myerson	Between Groups	48305.667	3	16101.89	2.181	0.122
	Within Groups	147668.33	20	7383.417		
	Total	195974	23			

* significant when $p < 0.05$

Table 2. Kruskal Wallis Test of Ivoclar teeth

Chi-Square	1.216
Df	3
P-value	0.749

* significant when $p < 0.05$

Table 3. ANOVA test for control and chemical groups

		Sum of Squares	Df	Mean Square	F	P-value
Control Groups	Between Groups	95518.778	2	47759.39	4.122	0.037*
	Within Groups	173803.5	15	11586.9		
	Total	269322.28	17			
Chemical Groups	Between Groups	131430.11	2	65715.06	5.737	0.014*
	Within Groups	171821.5	15	11454.77		
	Total	303251.61	17			

* significant when $p < 0.05$

Table 4. Kruskal Wallis test for mechanical and chemical + mechanical groups

	Mechanical Groups	Chemical + Mechanical Groups
Chi-Square	4.877	2.011
Df	2	2
P-value	0.087	0.366

*significant when $p < 0.05$

No significant difference was measured between the mechanical + chemical groups using the Kruskal Wallis test ($P\text{-value} = 0.366 > 0.05$) (Table 4).

Discussion

Three types of teeth were used: Major®, Myerson® and Ivoclar®. Each type has been divided into four retention modes: control, chemical, mechanical and chemical + mechanical.

After testing the samples and comparing each tooth within its own group, the resin Major® teeth, demonstrated better bond strength using dual chemical + mechanical retention than mechanical retention, and both control and chemical groups exhibited the least bond strength. The Ivoclar® teeth did not show a significant difference in mean bond strength between the different types of retention. Similarly, there was no significant difference in mean bond strength between the different types of retentions for the Myerson® teeth.

By comparing the different types of teeth having had the same type of retention, Ivoclar® demonstrated better bond strength for the control groups than the Major® and Myerson® teeth. Similarly, for chemical retention groups, Ivoclar® demonstrated better bond strength. Whereas for the mechanical and mechanical + chemical retention groups, there was no significant difference between the 3 types of teeth.

There have been great advancements in the technology and materials science of acrylic dentures for both totally and partially edentulous. This has led to a faster and easier impression procedure due to the computer-aided design/ computer-aided manufacturing technologies [13] and to prostheses that are more aesthetic and with better resistance. Several studies have investigated the prevalence of various denture repairs and found tooth loosening is

the most common repair. A survey by Darbar et al. in 1994 was used to calculate the prevalence of denture fractures and found that 33% of repairs performed were to correct loose teeth [6].

Evidence has been presented that the regular use of chemical disinfectants and cleaning agents could alter the denture bases' and dental materials' mechanical and physical properties leading to bond weakening and subsequent failure. These factors can cause tooth failure in an adhesive or cohesive manner or a combination of both. Adhesive failure occurs along the contact junction between the tooth and the denture acrylic base. It is characterized by the absence of a tooth fragment or denture base on the opposite surface. When the fracture occurs completely within the tooth or the base acrylic resin, it is called a cohesive fracture. However, if there is a fragment of the denture base material on the tooth surface or a portion of the tooth material on the denture base, it is a mixed failure mode [15].

Yadav et al. in 2015 reported that detachment occurs in the body of the tooth rather than in the acrylic interface of the tooth; thus, one will not need a surface treatment to cover the tooth [15]. Cardash et al. studied the effectiveness of

retention grooves. They determined that the force required to lift acrylic resin teeth from the denture base was almost similar to the force required to fracture the acrylic resin base [16]. Then in 1990, Cardash et al. compared vertical and horizontal retention grooves with respect to the bond strength between teeth and acrylic base, and they interpreted that the presence of prepared vertical retention grooves on the overlay area of the crest of the teeth improved retention with acrylic resin [17]. Similarly, Darbar et al. recommended using retention grooves because most detachments were adhesive [6]. In our study, not all detachments were of the cohesive type in the body of the tooth or the acrylic base. More than half had an adhesive detachment. 45 samples out of the 72 had adhesive detachment: 18 Major®, 15 Myerson® and 12 Ivoclar®. 27 had a cohesive or adhesive-cohesive detachment in the tooth shaft or base this fact highlights the higher retentive force existing between the tooth and the base (Figure 3). Hence the importance of studying and knowing what type of retention should be applied for better adhesion.

According to Consani et al. in 2014, whatever the polymerization

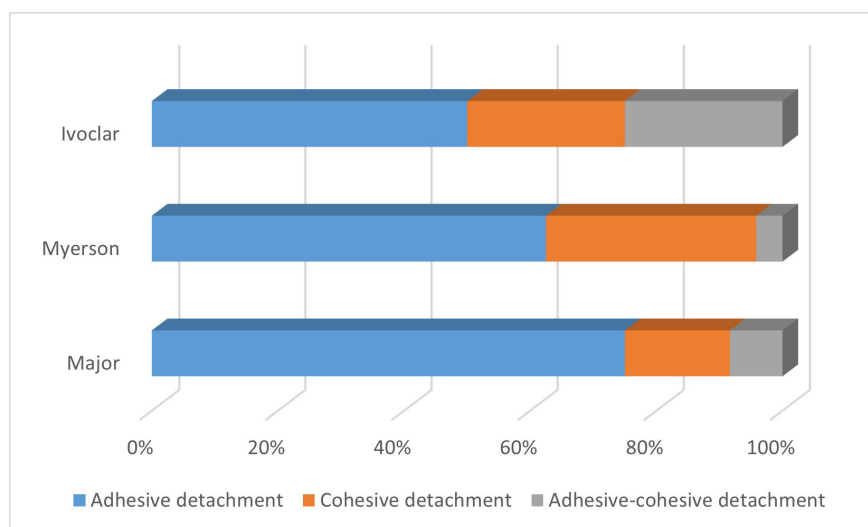


Figure 3. Frequency (in percentage) of failure modes.

cycle, there is no difference in the hardness of the thermosetting resin [18]. Takahashi demonstrated that heat-cured base resin significantly outperformed microwave-cured resin in bond strength, and both were better than cast resin [20]. Therefore, we used heat and pressure assisted self-polymerizing base resin.

Mahadevan et al. in 2015, compared the adhesion strength of resin teeth with different surface modifications. The first control group had an average of 274N, the second group, having undergone sandblasting, had an adhesion average of 339 N, the third chemically treated group had an average of 307 N and the fourth mechanically retained group had the highest average of 420 N [20]. Similarly, in this study, the average adhesion strength for Major® resin teeth were 211N for the control group, 212N for the chemical group, 330N for the mechanical group, and 380N for the mechanical + chemical group. For the Myerson® teeth, reticular, the following averages were measured 340N, 280N, 378N and 399N respectively. And for the Ivoclar® teeth, in composite, 383N, 417N, 463N and 469N were measured respectively. Can et al. evaluated the effect of retention grooves of different sizes on bond strength, and they concluded that the bond strength was increased by the mechanical retention applied on the ridge lap portion of the teeth and that the grooves on the ridge lap portion of the teeth effectively locked the teeth to the denture base [21]. All these studies show comparable results, which justifies that mechanical retention is necessary for better adhesion between the prosthetic tooth and the acrylic base. Similarly, Dandekri concluded that adhesion strength increases with the increasing surface area of prepared retentive grooves [22], and Vallittu obtained the highest bond strength by grinding grooves on the joint surface of an acrylic resin tooth before it was cured to acrylic resin denture bases [23].

On the other hand, Akin et al. in 2014, and Talahashi et al. in 2000, concluded that the application should treat the tooth surface of dichloromethane which results in a significant improvement in bond strength compared to the use of grooves [19-24]. But at the same time, they demonstrated that the use of grooves greatly improves the bond strength between acrylic denture bases and teeth because the resin from the denture base fills the groove space within the tooth structure creating a path of fracture resistance in a different direction, thereby strengthening the mechanical bond [24].

The adhesive should reinforce the bond between a prosthesis's base and teeth. However, the benefits of such an agent will be negated if traces of wax are not effectively removed from the tooth surface [1-2]. This may be why in a few studies they have found that chemical retention does not enhance adhesion hence the importance of wax removal methods

The development of cross-linked acrylic resin teeth solved the problems associated with the discoloration of acrylic teeth. The same reticulation acts as a double-edged sword regarding the bond between the base material of the denture and the teeth, because the more reticulations there are in the area of the ridge covering the weaker the bond between the base of the prosthesis and the tooth. For this, according to Jain, the region of the overlapping ridge of the reticulated teeth must be treated with dichloromethane for better bonding strength [25].

Grando et al. found no significant difference between several brands of teeth (Trilux, Soluut PX) [25]. Takahashi et al. demonstrated that conventional resin teeth possessed higher bond strength than cross-linked teeth [19]. Contrary to this study, the bond strength is related to the type of tooth and type of retention used: the Ivoclar® teeth, nano hybrids showed a greater

bond strength values than the other groups by comparing the control and chemical retention whereas for the mechanical and mechanical + chemical retentions, the same results were observed for all the groups.

This proves that it is necessary to study each type of tooth alone and test different types of retention to decide which type of retention to apply.

Based on the results obtained, the null hypotheses will be rejected. There was a significant difference between the types of teeth and the types of retentions used. The Ivoclar® teeth generally showed the highest values, as did the mechanical and mechanical + chemical retention types. Further investigation is needed regarding the addition of chemical agents to mechanical grooves.

Importance has been attributed to many factors involved in creating a bond between denture teeth and base acrylic resin, and in each case, there is evidence that each factor plays a role, but in some cases, the evidence may not seem strong. Yet, there is a general consensus that failure of the bond between prosthetic teeth and the base acrylic resin can have multiple causes, which may act separately or together to cause failure. It would therefore seem wise to adopt a technique that eliminates as many possible causes of failure. It follows that the detail-oriented dental technician is fundamental to achieving a good bond.

Limitation of the study

This research is, however, subject to several limitations. First, only high-impact resin material was used in our study. Therefore, further studies are needed using different types of denture base resins (conventional and high-impact resin materials). Second, further studies are needed with adjacent prosthetic teeth to the prosthetic tooth to be assessed to estimate better the bond strength with resin thickness that changes

in the presence of adjacent teeth. And finally, in this study, one type of cross-linked prosthetic teeth, one type of resin and one type of composite multilayer teeth were used. Various types of teeth are available in the market, which require further evaluation of bond strength.

Conclusion

There have been significant advances in the technology and material science of complete dental prostheses, with and without implants. This has led to complete dental prostheses that are with

better aesthetic and resistant. The problem of the detachment of the teeth from the base persists especially the anterior teeth, due to the forces applied to the palatal surface. The bond is the result of the sum of several criteria that must be taken into consideration.

After having applied several types of retention (control, chemical, mechanical, mechanical + chemical) on different types of teeth (Major®, Myerson® and Ivoclar®), this study used a universal machine, YLE Universal Testing Machine – strength mode, to evaluate the shear force between tooth and base and resins.

Results from this work shows that the multilayered teeth of the nano hybrid composite, Ivoclar®, had the highest bonding values in the control and chemical groups, and by applying mechanical or mechanical and chemical retention, there is no significant difference between the 3 types of teeth. And for resin teeth, it is better to apply a double retention.

In future studies, it would be interesting to compare if there is a difference in bond strength between the same types of teeth with the same retentions applied.

References

- 1- Kurt M, Saraç YŞ, Ural Ç, Saraç D. Effect of pre-processing methods on bond strength between acrylic resin teeth and acrylic denture base resin. *Gerodontology*. 2012 Jun;29(2):e357-62.
- 2- Cunningham JL. Shear bond strength of resin teeth to heat-cured and light-cured denture base resin. *Journal of oral rehabilitation*. 2000 Apr;27(4):312-6.
- 3- Barbosa DB, Barão VA, Monteiro DR, Compagnoni MA, Marra J. Bond strength of denture teeth to acrylic resin: effect of thermocycling and polymerisation methods. *Gerodontology*. 2008 Dec;25(4):237-44.
- 4- Patil SB, Naveen BH, Patil NP. Bonding acrylic teeth to acrylic resin denture bases: a review. *Gerodontology*. 2006 Sep;23(3):131-9.
- 5- CHUNG KH, Chung CY, Chung CY, Chan DC. Effect of pre-processing surface treatments of acrylic teeth on bonding to the denture base. *Journal of oral rehabilitation*. 2008 Apr;35(4):268-75.
- 6- Darbar UR, Huggett R, Harrison A. Denture fracture--a survey. *British dental journal*. 1994 May;176(9):342-5.
- 7- Huggett R, John G, Jagger RG, Bates JF. Strength of the acrylic denture base tooth bond. *British dental journal*. 1982 Sep 7;153(5):187-90.
- 8- Real-Osuna J, Almendros-Marqués N, Gay-Escoda C. Prevalence of complications after the oral rehabilitation with implant-supported hybrid prostheses. *Medicina oral, patologia oral y cirugía bucal*. 2011 Jul 15;17(1):e116.
- 9- Barpal D, Curtis DA, Finzen F, Perry J, Gansky SA. Failure load of acrylic resin denture teeth bonded to high impact acrylic resins. *The Journal of prosthetic dentistry*. 1998 Dec 1;80(6):666-71.
- 10- Yanikoglu DN, Duymus DZ, Bayindir DF. Comparative bond strengths of autopolymerising denture resin and light cured composite resin to denture teeth. *International dental journal*. 2002 Feb 1;52(1):20-4.
- 11- Cunningham JL, Benington IC. An investigation of the variables which may affect the bond between plastic teeth and denture base resin. *Journal of dentistry*. 1999 Feb 1;27(2):129-35.
- 12- Barbosa DB, Monteiro DR, Barão VA, Pero AC, Compagnoni MA. Effect of monomer treatment and polymerisation methods on the bond strength of resin teeth to denture base material. *Gerodontology*. 2009 Sep;26(3):225-31.
- 13- Yadav NS, Somkuwar S, Mishra SK, Hazari P, Chitumalla R, Pandey SK. Evaluation of bond strength of acrylic teeth to denture base using different polymerization techniques: A comparative study. *Journal of international oral health: JIOH*. 2015;7(Suppl 1):54.
- 14- Morresi AL, D'Amario M, Capogreco M, Gatto R, Marzo G, D'Arcangelo C, Monaco A. Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. *Journal of the mechanical behavior of biomedical materials*. 2014 Jan 1;29:295-308.
- 15- Masri G, Mortada R, Hatoum K, Al Harbi N, Boulos P, Salameh Z. Complete dentures fabricated using intraoral scanning and conventional techniques. *J Contemp Dent Pract*. 2020 Dec 1;21(12):1384-1388.
- 16- Cardash HS, Liberman R, Helft M. The effect of retention grooves in acrylic resin teeth on tooth denture-base bond. *The Journal of prosthetic dentistry*. 1986 Apr 1;55(4):526-8.
- 17- Consani RL, Folli BL, Nogueira MC, Correr AB, Mesquita MF. Effect of polymerization cycles on gloss, roughness, hardness and impact strength of acrylic resins. *Brazilian dental journal*. 2016 Mar;27:176-80.
- 18- Takahashi Y, Chai J, Takahashi T, Habu T. Bond strength of denture teeth to denture base resins. *International journal of prosthodontics*. 2000 Jan 1;13(1).
- 19- Mahadevan V, Krishnan M, Krishnan CS, Azhagarasan NS, Sampathkumar J, Ramasubramanian H. Influence of surface modifications of acrylic resin teeth on shear bond strength with denture base resin-an invitro study. *Journal of clinical and diagnostic research: JCDR*. 2015 Sep 1;9(9):ZC16.
- 20- Can G, Kansu G. An evaluation of the bond strength of plastic teeth to acrylic denture base material. *Ankara Universitesi Dis Hekimligi Fakultesi Dergisi= The Journal of the Dental Faculty of Ankara University*. 1990 Jan 1;17(1):97-101.
- 21- Dandekeri S, Mohandas S, Shetty SK, Ragher M, Rasheed M, Raj N. A study to assess the bond strength of acrylic teeth with different retentive features. *Journal of Pharmacy and Bioallied Sciences*. 2020 Aug 1;12(Suppl 1):S510-6.
- 22- Vallittu PK. Bonding of resin teeth to the polymethyl methacrylate denture base material. *Acta Odontologica Scandinavica*. 1995 Jan 1;53(2):99-104.
- 23- Akin H, Kirmali O, Tugut F, Coskun ME. Effects of different surface treatments on the bond strength of acrylic denture teeth to polymethylmethacrylate denture base material. *Photomedicine and laser surgery*. 2014

- 24- Jain G, Palekar U, Awinashe V, Mishra SK, Kawadkar A, Rahangdale T. The effect of different chemical surface treatments of denture teeth on shear bond strength: A comparative study. Journal of clinical and diagnostic research: JCDR. 2014 Jun 20;8(6):ZC15.
- 25- Grando M, Pacheco LM, Botega DM, Hirakata LM, Hilgert JB. Artificial teeth: Evaluation of wear resistance, microhardness and composition. Rev Gaúch Odontol 2015 Sep;63(3):263-70.
-