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COMPARISON OF DIFFERENT TYPES OF ORTHODONTIC BRACKETS AND ADHESIVE SYSTEMS ON THE TOTAL AMOUNT OF ARI INDEX ON THE TOOTH SURFACE

КОМПАРАЦИЈА НА РАЗЛИЧНИ ВИДОВИ ОРТОДОНТСКИ БРЕКЕТИ И АДХЕЗИВНИ СИСТЕМИ ВРЗ ВКУПНАТА КОЛИЧИНА НА ARI ИНДЕКС НА ЗАБНАТА ПОВРШИНА

Srbinovska O.[1], Muratovska A. I.[2], Spasova T. N.[1], Gavrilovikj I.[1], Pavovska P. A.[3]

[1]Department of Orthodontics, Ss. Cyril and Methodius University in Skopje, Faculty of Dentistry - Skopje, Republic of North Macedonia, [2]Department of Dental pathology and endodontics, Ss. Cyril and Methodius University in Skopje, Faculty of Dentistry – Skopje, Republic of North Macedonia, [3]Ss. Cyril and Methodius University in Skopje, Faculty of Pharmacy - Skopje, Republic of North Macedonia

Abstract

Aim: The purpose of this study is to determine the difference in the total amount of adhesive remnants when using different types of brackets bonded with different adhesive systems. The main hypothesis is based on the postulate that a stronger bond is created in porcelain brackets, applied with a system of total etch of the enamel, but with simultaneous appearance of a larger amount of adhesive remnants and enamel microcracks. **Material and method:** A total of 40 premolars, all extracted for orthodontic reasons, were divided into 4 groups. In groups 1 and 2, 10 metal and 10 porcelain brackets were bonded with the adhesive system of GC Fuji ORTHO LC and GC Fuji Ortho Conditioner (GC, Japan). In groups 3 and 4, 10 metal and 10 porcelain brackets were bonded with the adhesive system of OrmcoEnlight Light Cure Adhesive (Ormco, USA) and etching gel (Ivoclar, Vivadent, Liechtenstein).After 48 hours, all brackets were debonded. Using a microscope (Apochromatic Stereo Microscope ZEISS Stemi 508), we calculated the total area of the adhesive residue remaining on the tooth surface and on the bracket base surface expressed in µm2. We further used these values to obtain the adhesive remnant index using theARI formula. **Results:** The value of the ARI index was highest in Group 4: ORMCO PORCELAIN (78.45 ± 17.02) followed by Group 2: FUJI PORCELAIN (59.33 ± 17,129), followed by Group 3: ORMCO METAL (54.54 ± 11.67) and lowest in Group 1: FUJI METAL (44.81 ± 16, 86). **Conclusion:** In both adhesive systems (FUJI/ORMCO), the amount of adhesive remnants is without exception always higher in porcelain brackets compared to metal. The porcelain brackets that were bonded with RMGJC (FUJI) resulted in a lower ARI index values and enamel microcracks compared to the porcelain brackets bonded with composite resin (ORMCO). **Key words:** enamel damage, brackets, ARI index, adhesives, ultrasound

Апстракт

Цел: Целта на ова истражување е да се утврди разликата вовкупната количина на адхезивен остаток приупотреба на различни видови брекети бондирани со различен адхезивен систем. Главната хипотеза се базира на постулатот дека кај порцеланските брекети аплицирани со систем на тотално нагризување на емајлот се создавапојака врска, но со истовремена појава на поголемо количество адхезивен остаток имикропукнатини на емајлот. **Материјал и метод:** Вкупно 40 интактни премолари, сите екстархирани поради ортодонтски причини, беа поделени во 4 групи. Во група 1 и 2, 10 метални и 10 порцелански беа бондирани со адхезивниот систем на GC Fuji ORTHO LC и GC Fuji Ortho Conditioner (GC, Japan). Во група 3 и 4, 10 метални и 10 порцелански брекети беа бондирани со адхезивниот ситем наOrmco Enlight Light Cure Adhesive (Ormco, USA) иetching gel (Ivoclar, Vivadent, Liechtenstein). После 48 часа, сите брекети беа дебондирани. Користејќи микроскоп Apochromatic Stereo Microscope ZEISS Stemi 508), беше калкулирана вкупната површина на адхезивен остаток кој останува на забната површина и на базата на брекетата изразена во µm2. Овие вредности понатаму ги искористивме за да го пресметаме индексот на адхезивен остаток (ARI) користејќи ја ARI формулата. **Резултати:** Најголема вредност на ARI индекс добивме во Група 4: ORMCO PORCELAIN (78.45 ± 17.02), следено со група 2: FUJI PORCELAIN (59.33 ± 17,129), следено со група 3: ORMCO METAL (54.54 ± 11.67), а најниска вредност на ARI индекс добивме во група 1: FUJI METAL (44.81 ± 16, 86). **Заклучок:** И кај двата адхезивни системи(FUJI/ORMCO) адхезивниот остаток е без исклучок секогаш поголем кај порцеланските брекети споредено со металните. Притоа, порцеланските брекети кои беа бондирани со СМГЈЦ (FUJI) резултираа со помала вредност на на ARI индек и микропукнатини на емајлот во споредба со порцеланските брекети бондирани со композитна смола (ORMCO). **Клучни зборови:** емајлово оштетување, брикети, АРИ индекс , атхезиви, ултразвук

Introduction

The debonding process is used to remove the orthodontic attachments and all of the adhesive remnants from the tooth in order to restore the enamel surface to its original pre-treatment condition[1]. Many studies have shown that the process of debonding can cause enamel loss and its damage in the form of microcracks, scratches, grooves and even fractures, which are often visible to the nakedeye. These damages can compromise the integrity of the enamel and can cause aesthetic problems for the patiens[2].

Adhesives used to bond orthodontic brackets, such as composite resins, are considered to be the most important advances in clinical orthodontics[3,4]. Nowadays, the traditional technique of complete etch is widely accepted by most orthodontics as a routine procedure for bonding orthodontic brackets. However, this technique leads to the creation of a strong shear bond strength between the enamel and the bracket, which can lead to iatrogenic damage to the enamel surface during the debonding process of the brackets[1,3,5]. A factor that additionally affects the damage of the enamel surface is exactly the type of brackets used in the orthodontic therapy. Enamel damage of as much as 63.3%, was observed when porcelain brackets were debonded in an in-vitro study, which concluded that enamel damage was more likely to occur with porcelain brackets than with metal brackets[6].

The use of resin-modified glass ionomer cements, as orthodontic bonding agents, has been increased in the recent years. A factor that encourages their use is not only their ability to release fluoride but also the ability to reduce enamel loss during orthodontic treatment[7].

Determination of the ARI index (Adhesive remnant index) is a simple method that calculates the amount of adhesive remnants which remain on the tooth surface, after debonding the brackets, according to the formula of Artun and Bergland[8].

It must be noted that the ARI index depends on many factors, such as: the type of bonding technique (direct/indirect)[9], the type of bracket (metal, porcelain), the type of acid use for etching (orthophosphoric or polyacrylic)[7,10], the type of adhesive material (composite resin/glass-ionomer cement conventional or resin modified)[7], the position of the teeth in the jaw (front or buccal)[11], as well as the tooth surface on which the brackets are bonded (vestibular/lingual)[12].

The aim of this study is to determine the difference in the total amount of adhesive remnants when using different types of brackets bonded with different adhesive systems. The main hypothesis is based on the postulate that a stronger bond is created in porcelain brackets bonded with the system of total etch of the enamel, but with simultaneous appearance of a larger amount of adhesive remnants and enamel microcracks.

Material and method

Material:

- Teeth: 40 extracted permanent premolars
- Orthodontic brackets: 20 metal brackets and 20 porcelain brackets (Dentaurum, Germany)
- Adhesive systems:
    1. Resin modified glass-ionomer cement (GC Fuji ORTHO LC; GC Japan) and 10% polyacrylic acid (GC Fuji Ortho Conditioner; GC Japan),
    2. Composite resin (OrmcoEnlight Light Cure Adhesive; Ormco USA) and 37% orthophosphoric acid (IvoclarVivadent, Liechtenstein)
- Instruments for debonding brackets: orthodontic pliers (Dentaurum, Germany)

Method

The clinical trial was performed on 40 permanent premolars, all extracted for orthodontic reasons. The extracted teeth were intact, without enamel damage, restorations or carious lesions on the buccal surfaces. In order to avoid dehydration, the extracted teeth were stored in saline at a temperature of 37 OC .The specimens were divided into 4 groups:

Group 1 (FUJI METAL):Metal orthodontic brackets, bonded with the adhesive system of GC Fuji Ortho LC (GC, Japan), were applied on 10 extracted permanent premolars.

Group 2 (FUJI PORCELAIN):Porcelain orthodontic brackets, bonded with the adhesive system of GC Fuji Ortho LC (GC, Japan), were applied on 10 extracted permanent premolars.

Group 3 (ORMCO METAL): Metal orthodontic brackets, bonded with the adhesive system of OrmcoEnlight Light Cure Adhesive (Ormco, USA), were applied on 10 extracted permanent premolars.

Group 4 (ORMCO PORCELAIN):Porcelain orthodontic brackets, bonded with the adhesive system of OrmcoEnlight Light Cure Adhesive (Ormco, USA), were applied on 10 extracted permanent premolars.

Procedure

The buccal surfaces were cleaned with a pumice and water to eliminate plaque and other organic debris left after extraction, and then washed with distilled water and dried. The procedure is performed for all test specimens. Depending on the group of the sample, the brackets were bonded to the tooth surface according to the manufacturer's instructions.

- **Application procedure of the adhesive system of GC Fuji Ortho LC (GC, Japan):**

According to the manufacturer's instructions, the buccal surfaces of the samples are etched with GC Fuji Ortho Conditioner (10% polyacrylic acid) for 20 seconds and then washed for 20 seconds. It is important that conditioned surfaces remain moist. On a glass plate, 2 drops of liquid are applied and 1 teaspoon of powder, which is divided into two parts, whereby the first oneis mixed with all the liquid for 10 seconds, then the second part is added and mixed for 10-15 seconds. Thus prepared, the material is applied to the base of the bracket, and isthen positioned on the buccal surface of the tooth (the middle of the mesiodistal width and the middle of the gingivo-incisal length of the tooth) and pressed to release the excess adhesive. The excess is then removedand the adhesive is polymerized for 40 seconds.

- **Application procedure of the adhesive system of Ormco Enlight Light Cure Adhesive (Ormco, USA):**

According to the manufacturer's instructions, the buccal surfaces of the specimens were etched with 37% orthophosphoric acid for 30 seconds, washed for 30 seconds, and dried for 15 seconds until a white matte surface was obtained. Then, a thin layer of bond is applied to the etched surface and is polymerized for 20 seconds. Afterwards, a layer of Ormco Enlight adhesive is placed on the base of the bracket, then the bracket is positioned on the buccal tooth surface (in themiddleof the mesiodistal width and in the middle of the gingivo-incisal length of the tooth) and pressed to release excess adhesive. The excess adhesive is removed and the tooth is polymerized for 40 seconds.

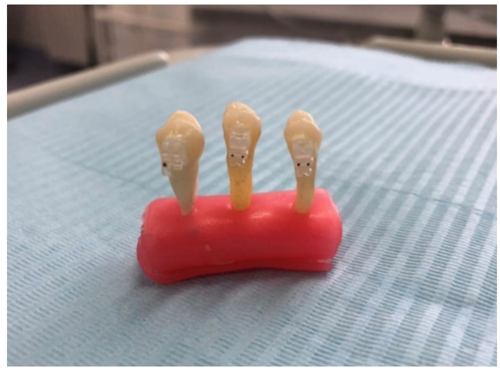
In order to achieve the maximum bond between the tooth surface and the bonded brackets, the dental specimens were stored in saline at room temperature for 48 hours. This is followed by debonding the brackets using orthodontic pliers from everyday clinical practice. The samples were coated with methylene blue, for easier microscopic detection of adhesive remnants at the brackets base,and on the tooth surface.

Microscopic analysis

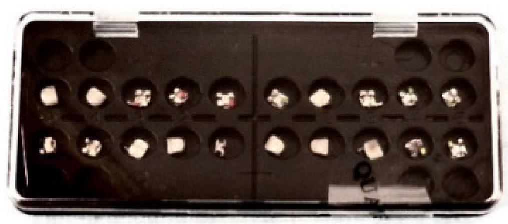
The remaining adhesive residues on the surface of the tooth and on the bracket are analyzed using microscopic analyses.The used microscope is Apochromatic Stereo Microscope ZEISS Stemi 508, with Axiocam ERc 5s camera (Carl Zeiss Microscopy GmbH, 2018) and 50 × (magnification) magnification of the surface. Using this microscope, we calculated the total area of the adhesive remnants remaining on the tooth surface and on the brackets base, expressed in μm^2.

Furthermore, we used these values to obtain the adhesive remnant index (ARI) according to Artun and Bergland8, which estimates the amount of adhesive that remains on the tooth surface after debonding the orthodontic brackets, and is calculated according to the following formula:

ARI = area of residual resin/area of bracket base x 100



Picture 1. *Applied porcelain brackets on*



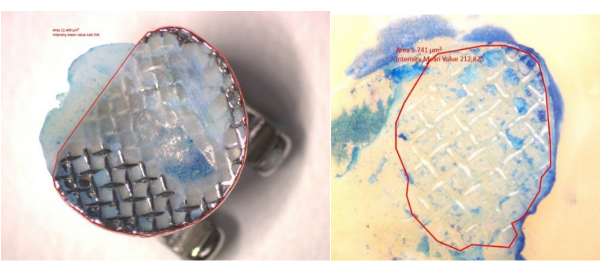
Picture 2. *Metal brackets*

Picture 3. *Apochromatic Stereo Microscope extracted premolars ZEISS Stemi 508*

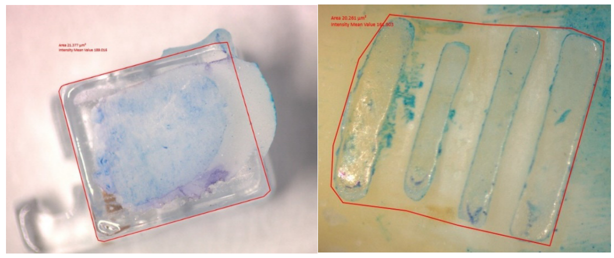
Picture 4. *Adhesive system Ormco Enlight LC (Ormco, USA)*

Picture 5. *Adhesive system GC Fuji Ortho LC (GC, Japan)*

Picture 6, 7. *Coating the teeth surfaces and bracket basewith methylene blue for easier detection of adhesive residues under a microscope*



Picture 8, 9. *Measurement of the total area of the metal bracket baseand the total area ofthe adhesive remnants left on the tooth surface in μm² after debonding metal bracket using a Microscope Apochromatic Stereo ZEISS Stemi 508*



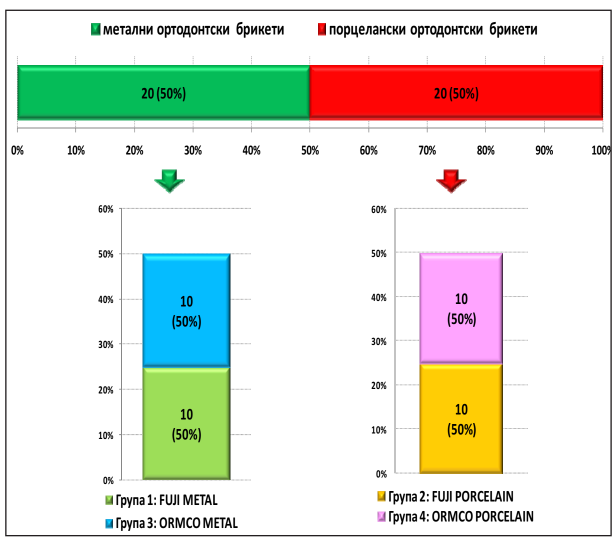
Picture 10, 11. *Measurement of the total area of the porcelain bracket baseand the total area ofthe adhesive remnants left on the tooth surface in μm² after debonding porcelain bracket using a Microscope Apochromatic Stereo ZEISS Stemi 508*

Results

The research is a prospective clinical study, which analyzed the change in the integrity of the enamel surface of the premolars.

The sample of 40 (100%) extracted permanent premolars was divided into 2 samples: a) 20 (50%) premolars with applied metal orthodontic brackets (Group 1 and Group 3), and b) 20 (50%) premolars with applied porcelain orthodontic brackets (Group 2 and Group 4). Each of the two samples of premolars (metal and porcelain) was divided into a group of 10 (50%) premolars with applied adhesive system - FUJI (Group 1 and Group 2.) and a group of 10 (50%) premolars with applied adhesive system ORMCO (Group 3 and Group 4) (Graph 1.).

For each of the examined premolars, the total area of adhesive remnants in μm2that remains at thebracket base was determined, i.e. the total area of adhesive remnants in μm2that remains on the tooth surface.



Graph 1. *Algorithm of procedures during the research*

Additionally, according to the obtained values, the adhesive remnant index (ARI) was determined, through which the amount of adhesive that remains on the tooth surface after debonding the brackets was estimated.

1. Comparison of ARI index - Group 1: FUJI METAL and Group 2: FUJI PORCELAIN

In group 1: FUJI METAL the average value of the ARI index after debonding the metal orthodontic brackets was **44.81 ± 16.86 µm²** with min/max. value of 21.43 / 68.09 µm².

In group 2: FUJI PORCELAIN the average value of the ARI index after debonding the porcelain orthodontic brackets was **59.33 ± 17.129 µm²** with a min/max. value of 33.74 / 81.10 m².

When comparing the two groups (Group 1: FUJI METAL/Group 2: FUJI PORCELAN), the analysis indicated that ***there wasno statistically significant difference*** in the height of the adhesive remnant index - ARI (Independent t-test: t (18) = - 1,911, p = 0.072). **We found that in group 2: FUJI PORCELAN, the height of the ARI index was insignificantly higher compared to group 1: FUJI METAL. (Table 1. and Graph 1.)**

2. Comparison of ARI index - Group 3: ORMCO METAL and Group 4: ORMCO PORCELAN

In Group 3: ORMCO METAL, the average value of the ARI index after debonding the metal orthodontic brackets was **54.54 ± 11.67µm²** with a min,/,max. value of 39.55 / 75.21µm²

In Group 4: ORMCO PORCELAN, the average value of the ARI index after debonding theporcelain orthodontic brackets was **78.45 ± 17.02 µm²** with min./max. value of 55.15 / 99.31 µm²

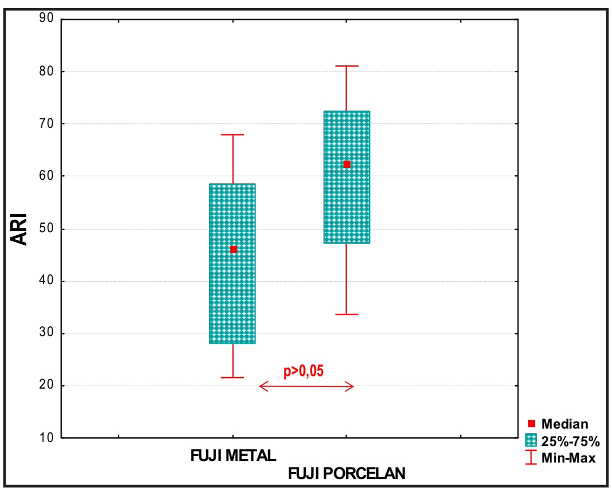
When comparing the two groups (Group 3: ORMCO METAL/Group 4: ORMCO PORCELAN), the analysis showed that ***there is a statistically significant difference*** in the height of the adhesive residue index - ARI (Mann Wihitney U test: Z = -2,873; p = 0.004). **We found that in Group 4: ORMCO PORCELAN, the height of the**

Table 1. Comparison of ARI index between Group 1: FUJI METAL

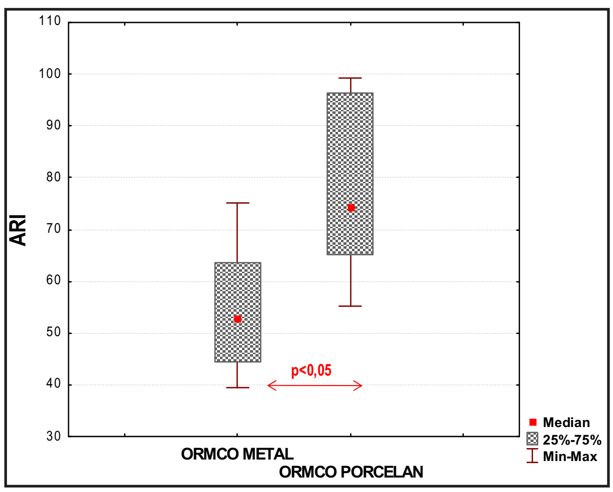
ARI	N	$\bar{X}$ ± SD	Std. Error	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Group 1: FUJI METAL	10	44,81±16,86	7,6011	(30,49)	1,45
Group 2: FUJI PORCELAN	10	59,33±17,129	7,6201	(30,65)	1,47
Independent t-test: t (18)=-1,911; p=0,072 significant for p<0,05					

Table 2. Comparison of ARI between Group 3: ORMCO METAL

ARI	N	$\bar{X}$ ± SD	Std. Error	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Group 3: ORMCO METAL	10	54,54±11,67	6,524	(37,61)	(10,19)
Group 4: ORMCO PORCELAN	10	78,45±17,02	6,524	(37,74)	(10,06)
Mann Wihitney U test: Z=-2,873; p=0,004* *significant for p<0,05					



Graph 1. Comparison of ARI index between and Group 2: FUJI PORCELAN, Group 1: FUJI METAL and Group 2: FUJI PORCELAN



Graph 2. Comparison of ARI index between Group 3 Group 4: ORMCO PORCELANORMCO METAL and Group 4: ORMCO PORCELAN

ARI index was significantly higher compared to Group 3: ORMCO METAL. (Table 2. and Graph 2.)

3. Comparison of ARI index between all four groups

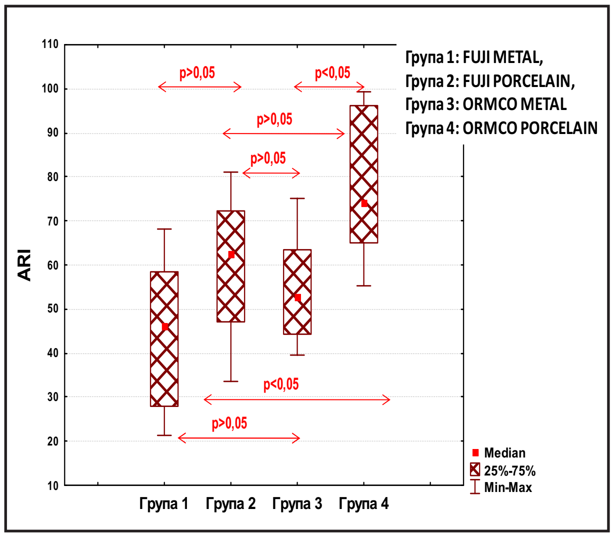
The analysis indicated that for p <0.5, **there is a statistically significant difference between the four groups** in terms of the height of the adhesive residue index - ARI (Kruskal-Wallis H test: Chi-square (3)=13,796; p= 0.003).

We found that the value of the ARI index **was highest in Group 4: ORMCO PORCELAN** (78.45 ± 17.02) followed by Group 2: FUJI PORCELAN (59.33 ± 17,129), followed by Group 3: ORMCO METAL (54.54 ± 11.67), **and the lowest value was observed in Group 1: FUJI METAL** (44.81 ± 16.86). In general, we concluded that in both adhesive systems (FUJI / ORMCO) **the adhesive residue is, without exception, always higher on the porcelain brackets compared to the metal ones.**

Table 1. Comparison of ARI index between all four groups

	ARI (μm2)				p
	Group 1: FUJI METAL	Group 2: FUJI PORCELAN	Group 3: ORMCO METAL	Group 4: ORMCO PORCELAN	
Groups	46,702	33,74	75,209	65,126	Kruskal-Wallis H test: Chi-square (3)=13,796; p=0,003*
	38,656	47,19	54,998	61,085	
	58,426	81,10	39,545	77,134	
	68,095	34,19	50,523	66,579	
	48,619	60,83	61,454	99,310	
	24,370	51,78	47,390	94,167	
	28,040	72,30	44,334	71,392	
	21,434	64,29	42,549	55,148	
	45,926	79,13	65,943	98,279	
	67,808	68,74	63,497	96,230	
$\bar{X}$ ± SD	44,81±16,86	59,33±17,129	54,54±11,67	78,45±17,02	

Гр 1/Гр 2 = Mann Wihitney U test: Z=-1,890; p=0,063
Гр 1/Гр 3 = Mann Wihitney U test: Z=-1,209; p=0,247
Гр 1/Гр 4 = Mann Wihitney U test: Z=-3,099; p=0,001*
Гр 2/Гр 3 = Mann Wihitney U test: Z=-0,756; p=0,481
Гр 2/Гр 4 = Mann Wihitney U test: Z=-1,965; p=0,052
Гр 3/Гр 4 = Mann Wihitney U test: Z=-2,873; p=0,004*
* сигнификантноза p<0,05



Graph 3. *Comparison of ARI index between all four-groups*

Discussion

The aim of this study was to determine the difference in the total amount of adhesive remnants when using different types of brackets bonded with different adhesive system. Additionally, the main hypothesis was based on a stronger bond that is created in porcelain brackets applied with a system of total etch of the enamel, but with the simultaneous appearance of a larger amount of adhesive remnants and enamel microcracks.

In their study, Lee and Lim[13] concluded that the type of adhesive used for bonding orthodontic brackets affects the amount of adhesive residue that remains on the tooth surface, i.e. from their results they concluded that resin-modified glass-ionomer cement has a lower value of ARI index compared to composite resin.

There is a direct correlation between the height of the ARI index and the shear bond strength[14]. The higher the bond strength, the higher the percentage of ARI[15]. According to the results of the author Uysal T. et al.[16], it was found that the bond strength of porcelain brackets is higher than that of metal brackets. In another study by Haidar et al.[17], the bond strength between light-polymerizing composite resin, light-polymerizing glass-ionomer cement, and light-curing compomer using metal and porcelain brackets, was compared. The shear bond strength was found to be significantly higher in porcelain brackets. The highest value of bonding strength was obtained in the group of porcelain brackets bonded with light-polymerizing composite resin (SBS = 20.17 MPa), and the lowest in metal brackets bonded with light-polymerizing glass-ionomer cement (SBS=4.45MPa).

Reynolds[18] suggested that a minimum bond strength of 5.9-7.8 MPa was sufficient to bond the brackets to the enamel surface, while Lopez et al.[19] found that a bond strength of 7MPa ensured the clinically successful bonding of orthodontic brackets. Resin-modified GJCs have a lower bond strength (SBS) compared to composite resin, but according to new studies, this is quite sufficient for successful orthodontic bonding.

From the results obtained in our research, comparing all four groups individually we found that the value of ARI was highest in group 4: ORMCO PORCELAN (78.45 ± 17.02) followed by group 2: FUJI PORCELAN (59.33 ± 17,129), followed by group 3: ORMCO METAL (54.54 ± 11.67), and lowest value was observed in group 1: FUJI METAL (44.81 ± 16.86). In general, we can conclude that in both adhesive systems (FUJI / ORMCO) the adhesive remnant is without exception always higher on porcelain brackets compared to metal brackets.

We have the best result in group 1 (FUJI METAL), which is due to the lower bond strength created between the enamel and the resin-modified glass-ionomer cement when compared to the strength of the composite resin, which consequently results in a smaller amount of adhesive remnants (ARI). In addition, we have a stronger chemical bond that is created with porcelain brackets, compared to metal, which increases the risk of fractures or damage to the enamel. We can therefore confirm the main hypothesis, which is based on a stronger bond that is created in porcelain brackets, applied with a system of total etch of the enamel, but with the simultaneous appearance of a larger amount of adhesive remnants and enamel microcracks.

At the same time, our results coincide with those of N.J. Cochrane et al.[20] who concluded that enamel damage was more common in porcelain brackets (31.9%) compared to metal brackets (13.3%), therebythe porcelain brackets bonded with a resin-modified glass-ionomer cement resulted in lower enamel damage compared to porcelain brackets bonded with composite adhesive systems.

Conclusion

- The type of bracket affects the damage to the enamel surface. Metal brackets are a better choice than porcelain because the bonding strength of porcelain brackets is higher than that of metal, and their hardness is higher than that of enamel, which in the process of debonding increases the risk of damage to the enamel surface, in the form of microcracks and fractures of the enamel.
- The type of adhesive affects the amount of adhesive residue that remains on the enamel surface, i.e. according to our results, SMGJC (Fuji Ortho LC) has a lower value of ARI index compared to composite resin (OrmcoEnlight). In addition, it has other advantages such as fluoride release, easy removal, and lower risk of damage compared to the traditional total etch technique.
- There is a correlation between the ARI index and the bond strength, i.e. the higher the bond strength the higher the ARI index. It has been proven that the shear bond strength in composite resin is higher compared to that of SMGJC, which is confirmed by our results.

Reference

1. Ahrari F, Akbari M, Akbari J, Dabiri G. Enamel surface roughness after debonding of orthodontic brackets and various clean-up techniques. J Dent (Tehran). 2013;10(1):82-932.
2. Heravi F, Shafaee H, Abdollahi M, Rashed R. How Is the Enamel Affected by Different Orthodontic Bonding Agents and Polishing Techniques?. J Dent (Tehran). 2015;12(3):188–194.
3. Vicente A, Bravo LA, Romero M. Influence of a nonrinse conditioner on the bond strength of brackets bonded with a resin adhesive system. Angle Orthod 2005; 75: 400-405.
4. Scougall Vilchis RJ, Yamamoto S, Kitai N, Hotta M, Yamamoto K. Shear bond strength of a new fluoride-releasing orthodontic adhesive. Dent Mater J. 2007 Jan;26(1):45-51. doi: 10.4012/dmj.26.45. PMID: 17410892.
5. Bishara SE, Fonseca JM, Boyer DB. The use of debonding pliers in the removal of ceramic brackets: Force levels and enamel cracks. Am J Orthod Dentofac Orthop 1995; 108: 242-248.
6. Redd TB, Shivapuja PK. Debonding ceramic brackets: effects on enamel. J Clin Orthod. 1991;25:475–481.
7. Ireland AJ, Hosein I, Sherriff M. Enamel loss at bond-up, debond and clean-up following the use of a conventional light-cured composite and a resin-modified glass polyalkenoate cement. Eur J Orthod 2005;27:413-419.
8. Montasser M.A.; Drummond J.L. : Reliability of the Adhesive Remnant Index Score System with Different Magnifications, Angle Orthodontist, Vol 79, No 4, 2009
9. Vidor MM, Felix RP, Marchioro EM, Hahn L. Enamel surface evaluation after bracket debonding and different resin removal methods. 2015 Mar-Apr; 20(2): 61–67.
10. Fjeld M, Øgaard B. Scanning electron microscopic evaluation of enamel surfaces exposed to 3 orthodontic bonding systems. Am J Orthod Dentofacial Orthop. 2006;130(5):575-581. doi:10.1016/j.ajodo.2006.07.002
11. Knoll M, Gwinnett AJ, Wolff MS. Shear strength of brackets bonded to anterior and posterior teeth. Am J Orthod. 1986;89(6):476-479. doi:10.1016/0002-9416(86)90003-5
12. Brosh T, Strouthou S, Sarne O. Effects of buccal versus lingual surfaces, enamel conditioning procedures and storage duration on brackets debonding characteristics. J Dent. 2005;33(2):99-105. doi:10.1016/j.jdent.2004.08.005
13. Lee YK, Lim YK. Three-dimensional quantification of adhesive remnants on teeth after debonding. Am J Orthod Dentofacial Orthop. 2008;134(4):556-562.
14. Faria-Júnior ÉM, Guiraldo RD, Berger SB, Correr AB, Correr-Sobrinho L, Contreras EF. In-vivo evaluation of the surface roughness and morphology of enamel after bracket removal and polishing by different techniques. Am J Orthod Dentofacial Orthop. 2015;147(3):324–329

15. Osorio R, Toledano M, García-Godoy F. Enamel surface morphology after bracket debonding. ASDC J Dent Child. 1998;65(5):313-354.
16. Uysal T, Ustdal A, Kurt G. Evaluation of shear bond strength of metallic and ceramic brackets bonded to enamel prepared with self-etching primer. Eur J Orthod 2010; 32: 214-8.
17. Haydar B, Sarikaya S, Cehreli ZC. Comparison of shear bond strength of three bonding agents with metal and ceramic brackets. Angle Orthod 1999 Oct; 69(5): 457-62
18. Reynolds IR, von Fraunhofer JA. Direct bonding of orthodontic attachments to teeth: the relation of adhesive bond strength to gauze mesh size. British J Orthod 1976 Apr; 3(2): 91-5.
19. Lopez JI. Retentive shear bond strengths of various bonding attachment bases. Am J Orthod 1980 Jan; 77(1): 669-78
20. Cochrane NJ, Lo TWG, Adams GG, Schneider PM. Quantitative analysis of enamel on debonded orthodontic brackets. Am J Orthod Dentofacial Orthop. 2017;152(3):312-319. doi:10.1016/j.ajodo.2017.01.020