Assessment of tensile strength between base-repair materials and porcelain teeth subjected to different surface treatment

Farklı yüzey işlemi uygulanan porselen dişler ve kaide-tamir materyalleri arasındaki gerilme kuvvetinin değerlendirilmesi

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SUMMARY

Aim: The purpose of study is to assess the tensile strength between porcelain teeth and two different denture base (polyamide and heat-polymerized acrylic), a repair material (auto-polymerizing acrylic) after different types of surface treatment.

Materials and Methods: Total of 63 same form and color mandibular right first molar porcelain denture teeth were used. The first molar porcelain denture teeth were separated into 3 material groups; Group 1: Heat-polymerized (HP), Group 2: Autopolymerizing (AP), and Group 3: Polyamide (PA) (n=21). Then, all material groups were divided into 3 subgroups (n=7) representing different surface treatment method; Control, Airborne abrasion, Er: YAG laser. A universal testing machine was used for determining the tensile bond strength (MPa) of the porcelain denture teeth to surface treated denture base and repair materials. The crosshead speed was set of 0.5 mm/min. Two-way ANOVA and post-hoc Tukey's HSD was used for statically analyses ($\alpha=0.05$). The effects of the surface treatment were observed by scanning electron microscopy (SEM).

Results: The polyamide (PA) has significantly higher ($p< 0.05$) tensile bond strength than the Heat-polymerized (HP) and Auto-polymerizing acrylic (AP). Polyamide (PA) with laser surface treatment (9.89 MPa) showed highest tensile bond strength. The lowest tensile bond strength was determined control group (6.38 MPa) of auto-polymerizing (AP). Surface treatments showed no significant difference.

Conclusion: Superior tensile strength was found polyamide denture base and different surface treatments not affect the tensile strength of porcelain teeth.

Keywords: Artificial porcelain teeth, acrylic resins, polyamide, tensile strength

ÖZET

Amaç: Bu çalışmanın amacı, porselen protez dişelere uygulanan farklı yüzey işlemlerinden sonra iki farklı protez kaide (poliamid ve ısı ile polimerize akrilik) ve tamir materyali (otopolimerize akrilik) ile arasındaki gerilme kuvvetini değerlendirmektir.

Gereç ve Yöntem: Bu çalışmada 63 adet aynı şekil ve renk mandibular sağ birinci molar porselen protez dişleri kullanıldı. Birinci molar porselen protez dişler 3 materyal grubuna ayrıldı; Grup 1: Isı polimerizasyonu (HP), Grup 2: Otopolimerize akrilik (AP) ve Grup 3: Poliamid (PA) (n=21). Daha sonra, tüm poselen dişler yüzey işleme yöntemine göre 3 alt gruba ayrıldı; Kontrol, Kumlama, Er: YAG lazer. Gerilme kuvveti (MPa) universal test makinesi kullanılarak (0.5 mm/dak) tespit edildi. Gerilme değerlerinin ortalama ve standart sapması hesaplandı ve tüm veriler two-way ANOVA ve post-hoc Tukey HSD ile analiz edildi. Güven aralığı $\alpha=0.05$ olarak belirlendi. Yüzey işlemlerinin etkileri taramalı elektron mikroskobu (SEM) ile incelendi.

Bulgular: Poliamid kaide materyali diğer materyallere göre

önemli derecede yüksek gerilme değeri sağladı (p<0,05). En yüksek gerilme değeri, lazer işlemi uygulanan porselen yüzeyler ile poliamid kaide materyali (9,89 MPa) arasında bulundu. En düşük gerilme değeri, otopolimerize akrilik tamir materyalinin kontrol grubu (6,38 MPa) olarak belirlendi. Uygulanan yüzey işlemleri istatiksel anlamlı bir fark göstermedi (p>0,05).
Sonuç: En fazla gerilme kuvveti poliamid kaide materyalinde bulunmuştur. Farklı yüzey uygulamalarının porselen dişlerin gerilme değerlerini etkilemediği görülmüştür.

Anahtar kelimeler: yapay porselen diş, akrilik rezin, poliamid, gerilme kuvveti

INTRODUCTION

Polyamides, thermoplastic polymers, are produced by the condensation reactions between a diamine and a dibasic acid.[1-3] Currently, thermo-injectable polyamides are alternatively used as a denture base contrary to conventional acrylic resins due to some advantages such as superior esthetic, more safety for allergic reaction, enough strength and higher elasticity than common heat-polymerizing resins.[4-8] In addition using injection moulding technique for polyamide laboratory procedure can eliminate increasing vertical dimension of prosthesis and altering denture teeth occlusion. However, polyamides have several problems such as base color change, stain and rough surface in short period of time, difficulty polishing procedure, high water sorption, bacterial contamination, more elasticity and utilizing the undercuts of denture teeth for retention.[4,9,10]

Clinically, the use of porcelain teeth has some advantageous due to its long time color stability, hardness or high wear resistance than acrylic teeth.[11] However, porcelain denture teeth are not bond chemically, they are connected to the acrylic resin denture bases by mechanically retention (diatoric undercuts or metal pins). The retention area is higher. It concentrates stress and it leads to the most common failure between denture teeth and base material.[12] Clinically the most common failure of denture teeth is repaired by using self-cured or heat-cured polymethylmethacrylate (PMMA). However, using cold-cured repairs showed lower bond strength than heat-cured repairs. There are many studies about surface treatment (etching, silane coating, high energy abrasion, and ceramic primer application) to increase retention between porcelain and denture base material and self-cured PMMA.[13-16]

However, no research has detected the tensile strength between porcelain teeth subjected to different surface treatment and newly developed polyamide denture base material.

The aim of this study is to assess the tensile strength between porcelain teeth and two different denture bases (polyamide and heat-polymerized acrylic), a repair material (auto-polymerizing acrylic) after different types of surface treatment. The authors hypothesize that (1) different denture base and repair material have no effect on the bond strength of porcelain teeth and (2) porcelain teeth subjected to different surface treatment have no difference on bond strength.

MATERIALS AND METHODS

Specimen preparation

Two types of commercially available denture base materials and 1 repair material were tested in this study: a polyamide (PA) (Deflex, Nuxen SRL, Argentina), a heat-polymerized acrylic (HP) (QC-20 Dentsply, De Trey, Addlestone, UK) and an auto-polymerizing acrylic (AP) (Takilon, Rodent, Milan, Italy).

A total of 63 same form and color mandibular first right molar porcelain denture teeth (Natura Dent Vita, Zahnfabrik Bad Nauheim, Germany) were used. Porcelain denture teeth have diatoric undercuts (3x3mm cylinder and two proximal hole) for mechanical retentive (Fig. 1A and 1B).

Fig. 1A. Diatoric undercuts of sample

Fig. 1B. Diatoric undercuts of sample

Each diatoric retention surface (except proximal holes) was polished under running water using abrasive papers from #100 to #600 (Norton; Saint-Gobain Abrasivos Ltda). The polished porcelain teeth were randomly divided into 3 material groups; Group 1 heat-polymerized (HP), Group 2 auto-polymerizing (AP), and Group 3 Polyamide (PA) (n=21). Then, all material groups were separated into 3 subgroups (n=7) representing surface treatment methods; Control group untreated, Abrasion group (airborne-particle abrasion with 250-mm Al_2O_3, 10 seconds at 0.2 MPa pressure, 10 mm distance); Er:YAG laser group [2940 nm wavelength, 0.8 mm spot size, 10 Hz pulse frequency, 150 mJ pulse energy, 100ms pulse duration, 60 seconds application time, 10mm distance (Doctor Smile; Lambda SpA, Vicenza, Italy)]. After surface treatment; a mold (3-mm diameter, 4 mm high) was prepared from silicone to standardize the size of specimen. With the help of silicone mold, pink wax-porcelain teeth combination was produced. Then, the combinations were invested in dental stone. The specimen of HP group was polymerized in water 9 hours and 74 °C in a thermal chamber (Termotron P-100, Brazil). The specimens of AP group were polymerized under pressure (55 °C, 15 minutes). The specimen of polyamide group (PA) was prepared according to manufacturer's instructions using injection molding technique under 5 bars for 1 minute. After polymerization of specimen, all samples were stored were then stored. They were stored in distilled water (37±1°C, 24 hours).

Experimental method

The testing diagram is shown in Figure 2A.

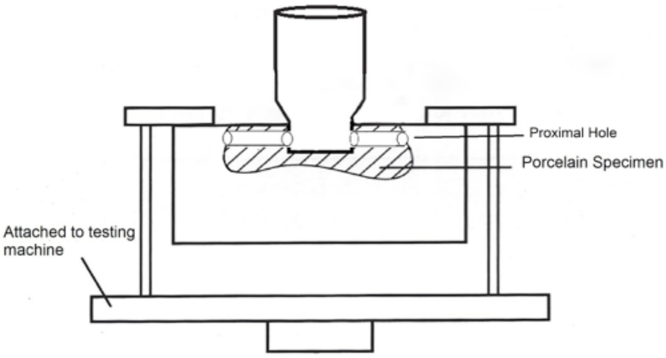

Fig. 2A. Testing diagram

The tensile load was applied perpendicular to the ridge-lap porcelain tooth surface (Fig. 2B)

Fig. 2B. A sample of PA group

by using, crosshead speed 5 mm/min, universal testing machine (8501, Instron Corp). The tensile strength was recorded when failure occurred in the bonding area of porcelain tooth. The values of tensile bond strength (α) were calculated through the formula: α=L/A, where α is tensile strength (MPa), L is the load at failure (N) and A is the adhesive area (mm2).

Scanning electron microscopy (SEM) analyses

To evaluate change in porcelain denture teeth, ridge-lap surface was studied by selecting examples in each experimental group. The samples were evaluated under SEM (Zeiss EVO LS 10; Carl Zeiss, Nanterre, France) with 15kv at magnification 2000x. The surface image of samples, coated with 80% gold and 20% palladium at the 3μm thickness, was taken.

Statistical analyses

All data were statically analyzed by using two-way ANOVA, comparing surface treatment and material as independent factors. The post-hoc Tukey HSD multiple comparisons test was used to determine the mean differences (SPSS statistical software v16.0, SPSS, Chicago, IL, USA). The confidence level was set at α= 0.05.

RESULTS

Result of tensile bond strength of specimens are listed in (Table 1). A two-way ANOVA (Table 2) and Tukey HDS (Table 3)

Table 1. Means and Standard Deviations of the Tensile Bond Strength of Specimens (MPa)

Surface Treatments	Materials		
	AP	HP	PA
Control	6.3829^Aa^ (3.056)	8.1957^Aa^ (1.341)	9.4343^Ba^ (1.033)
Air abrasion	7.7143^Aa^ (2.613)	6.5700^Aa^ (.992)	8.5300^Ba^ (1.698)
Laser	7.3143^Aa^ (1.623)	7,6043^Aa^ (1.171)	9,8900^Ba^ (1.115)

Table 2. Two-way ANOVA analyzes

Source	Sum of Squares	*Df*	Mean Square	F	*P*
Material	56.394	2	28.197	9.015	.000
Surface Treatment	4.703	2	2.352	.752	.476
Material×Surface Treatment	18.018	4	4.505	1.440	.233
Error	168.896	54	3.128		
Total	4239.314	63			

Table 3. Tukey HSD multiple comparisons test

Materials	Subset	
	1	2
Auto-polymerizing (AP)	7.1371	
Heat-polymerized (HP)	7.4567	
Polyamide (PA)		9.2848

are shown for comparisons among surface treatment and between materials (α=0.05). Significant differences were found for materials ($p<0.05$); however, no significant differences were observed for surface treatment and interaction between the factors ($p>0.05$).

The tensile strength of the PA was significantly higher ($p<0.05$) than with AP and HP. However, no significant difference was found between AP and HP materials ($p>0.05$). The highest tensile bond strength was found with PA with laser porcelain surface (9.89 MPa). The lowest tensile bond strengths were determined in AP resin control group (6.38 MPa). The laser and airborne particle surface treatment showed a decrease in tensile strength of HP group, while it showed an increase in tensile strength of AP group. For PA specimens, laser surface treatment was found to increase the bonding strengths, while airborne particle surface treatment was found to decrease. However, all surface treatments showed no significant differences (p>0.05).

The microstructure of the porcelain denture teeth surface was examined by SEM (X2000). Each group was tagged between Figure 3A-C.

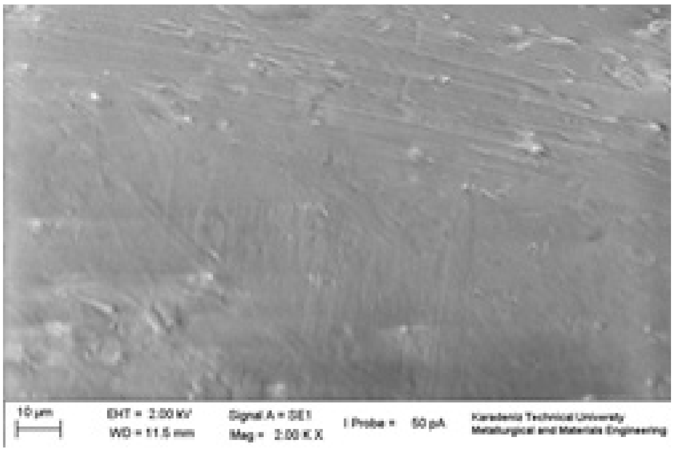

Fig. 3A. SEM micrographs of Control group (2000x)

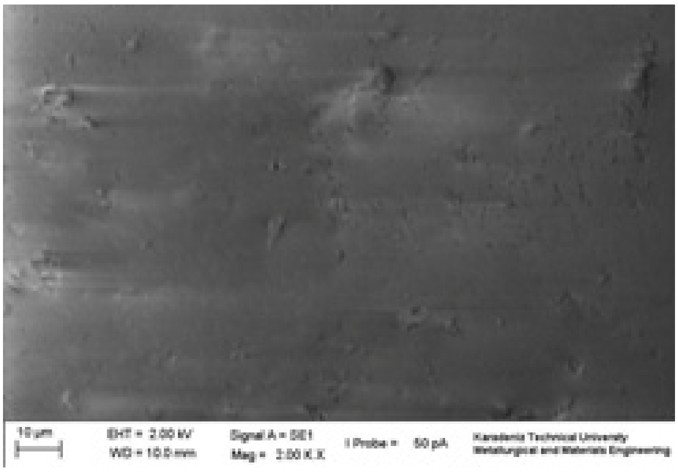

Fig. 3B. SEM micrographs of Airborne abrasion group (2000x)

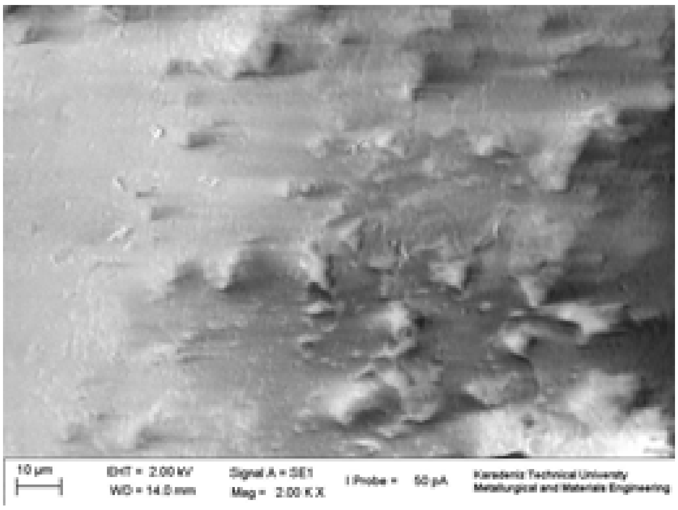

Fig. 3C. SEM micrographs of Er:YAG laser group (2000x)

The Control group mentioned above showed many uniform parallel scratches formed by abrasive papers during the abrasion (Fig. 3A). The Laser and Airborne abrasion surface treatment resulted in various deep irregularities on the ridge-lap surface of porcelain denture teeth. In Airborne abrasion group showed irregular shape less than 10 µm in size, while Er:YAG laser group had irregular shape size larger than10 µm. (Fig. 3B and 3C).

DISCUSSION

Based on this study; the first hypothesis, stating that different denture base and repair material have no effect on the bond strength of porcelain teeth, was rejected. However; the second hypothesis, porcelain teeth subjected to different surface treatment have no difference on bond strength, was accepted.

Previous studies attempt to improve the bond strength of denture teeth to the acrylic resin denture base via ridge lap surface modification such as chemical treatment or mechanical modification. Chemical etch applications (methyl methacrylate monomer, chloroform, acetone, ethylene chloride, ethyl acetate, dichloromethane) may change the morphology and chemical properties of the materials.[17-23] Commonly methyl methacrylate monomer chemical agent is used to increase bond strength of denture tooth retention. Some authors obtained that wetting the ridge-lap surface with methyl methacrylate monomer increased bond strength between denture tooth and acrylic resin.[24-26] However, Spratley found that wetting the ridge-lap surface with methyl methacrylate monomer did not significantly change bond strength.[27] In addition, Morrow .[28] concluded that using methyl methacrylate monomer for wetting the ridge-lap surface of plastic teeth significantly decreased bond strength.

Other way to increase bond strength between denture tooth and acrylic resin is mechanical retention (metal pins or diatoric undercuts, grinding or grooving, roughening with sandblasting and burs, laser treatment) on ridge lap surface of denture tooth. Meng .[23] evaluated the effect of surface treatment on bond strength between the denture teeth and the auto-polymerized acrylic resin. Result of the study, diatoric macro retention systems showed higher bond strengths compared to control group. Effect of retention grooves size and shape on ridge lap surface were discussed by previous studies. Can and Kansu[29] concluded that increase of retention grooves size on ridge lap enhanced bond strength between denture tooth and acrylic. Cardash .[30] compared the vertical and horizontal retention grooves shape on ridge lap of denture tooth and observed that vertical retention shape has a significant advantage on bond strength. However, Cunningham and Benington[31] found that vertical grooves and surface modification with burs have no significant difference in the bond strength of denture tooth.

Chung .[32] assessed the effect of sandblasting and surface modification with burs on ridge lap surface and concluded that both surface treatments increased bond strength between denture teeth and acrylic base material. However, in the current study we found that the air bone sandblasting does not significantly change in bond strength between material and porcelain denture teeth. This might be the process of air bone sandblasting. It did not affect surface morphology for ceramic surface area. The polyamide denture base obtained higher tensile bond strength than the other materials. These results may be connected to the fact that polyamide polymer melted at a high preheated degree and it was injected with pressure, thus it penetrated into proximal retention hole undercut.

In this study, Er:YAG laser-treated specimens had higher bond strength values, although the difference was not statistically significant. This is in agreement with Akin .[33] and Alkurt .[34] finding that laser surface treatment increased bond strength compared to the control group specimens. However, Gundogdu .[35] reported that altering the PMMA surface with an Er:YAG laser was ineffective.

The limitation of this study is that the tensile bond strength of porcelain denture was evaluated only two types of surface treatment. Further study is needed to evaluate effect of other surface treatment on tensile bond strength between porcelain denture teeth and denture materials.

CONCLUSIONS

Clinical significance

In the comparison of tensile bond strength between porcelain denture teeth and two different denture bases (polyamide and heat-polymerized acrylic) and a repair material (auto-polymerizing acrylic), significant differences were found among the materials. Using two different surface treatments (Airborne abrasion, Er:YAG laser) showed no significant change in tensile bond strength.

Based on the present *in vitro* study, we can conclude that;

- The Polyamide (PA) has higher tensile bond strength than the Heat-polymerized (HP) and Auto-polymerizing acrylic (AP).
- Laser and air bone sandblasted surface treatment did not significantly affect tensile bond strength.

REFERENCES

1. Matthews E, Smith DC. Nylon as a denture base material. Br Dent J 1955; 98: 231-237.

2. Watt DM. Clinical assessment of nylon as a partial denture base material. Br Dent J 1955; 98: 238-244.

3. Hallett GEM, Farrell JH. Nylon denture base. Dent Pract 1956; 6: 239-240.

4. Hargreaves AS. Nylon as a denture-base material. Dent Pract Dent Rec 1971; 22: 122-128.

5. Stafford GD, Huggett R, MacGregor AR, Graham J. The use of nylon as a denture-base material. J Dent 1986; 14: 18-22.

6. Parvizi A et. al. Comparison of the dimensional accuracy of injection-molded denture base materials to that of conventional pressure-pack acrylic resin. J Prosthodont 2004; 13: 83-89.

7. Yunus N, Rashid AA, Azmi LL, Abu-Hassan MI. Some flexural properties of a nylon denture base polymer. J Oral Rehabil 2005; 32: 65-71.

8. Katsumata Y et. al. Mechanical characterization of a flexible nylon denture base material. Bull Kanagawa Dent Col 2007; 35: 177-182.

9. MacGregor AR, Graham J, Stafford GD, Huggett R. Recent experiences with denture polymers. J Dent 1984; 12: 146-157.

10. Yunus N, Rashid AA, Azmi LL, Abu-Hassan MI. Some flexural properties of a nylon denture base polymer. J Oral Rehabil 2005; 32: 65-71.

11. Craig RG. Prosthetic appliance of polymers. In: Robert G. Craig, John M. Powers, editors. Restorative Dental Materials. 11th ed. St Louis; CV Mosby, 2002. p. 570-571.

12. Darbar UR, Huggett R, Harrison A. Denture fracture-a survey. Br Dent J 1994; 176: 342-345.

13. Sumithra N, Waknine S, Schulman A. Bond strength of etched porcelain denture teeth of PMMA. Quintessence Int 1986; 17: 745-748.

14. Paffenbarger GC, Sweeney WT, Bowen RL. Bonding porcelain teeth to acrylic resin denture bases. J Am Dent Assoc 1967; 74: 1018-1023.

15. Moffa JP, Jenkins WA, Weaver RG. Silane bonding of porcelain denture teeth to acrylic resin denture bases. J Prosthet Dent 1975; 33: 620-627.

16. Marchack BW, Yu Z, Zhao XY, White SN. Adhesion of denture tooth porcelain to heat-polymerized denture resin. J Prosthet Dent 1995; 74: 242-249.

17. Rached RN, Del-Bel Cury AA. Heat-cured acrylic resin repaired with microwave-cured one: bond strength and surface texture. J Oral Rehabil 2001; 28: 370-375.

18. Vallittu PK, Lassila VP, Lappalainen R. Wetting the repair surface with methyl methacrylate affects the transverse strength of repaired heat-polymerized resin. J Prosthet Dent 1994; 72: 639-643.

19. Shen C, Colaizzi FA, Birns B. Strength of denture repairs as influenced by surface treatment. J Prosthet Dent 1984; 52: 844-848.

20. Rached RN, Powers JM, Del Bel Cury AA. Repair strength of autopolymerizing, microwave, and conventional heat-polymerized acrylic resins. J Prosthet Dent 2004; 92: 79-82.

21. Minami H, Suzuki S, Minesaki Y, Kurashige H, Tanaka T. In vitro evaluation of the influence of repairing condition of denture base resin on the bonding of autopolymeri-

zing resins. J Prosthet Dent 2004; 91: 164-170.
22. Sarac YS, Sarac D, Kulunk T, Kulunk S. The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. J Prosthet Dent 2005; 94: 259-266.
23. Meng GK, Chung KH, Fletcher-Stark ML, Zhang H. Effect of surface treatments and cyclic loading on the bond strength of acrylic resin denture teeth with autopolymerized repair acrylic resin. J Prosthet Dent 2010; 103: 245-252.
24. Rupp NW, Bowen RL, Paffenbarger GC. Bonding cold-cure acrylic resins to acrylic resin teeth. J Am Dent Assoc 1971; 83: 601-606.
25. Geerts G, Jooste CH. A comparison of the bond strengths of microwave- and water bath-cured denture material. J Prosthet Dent 1993; 70: 406-409.
26. Saavedra G et. al. Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling. Int J Prosthodont 2007; 20: 199-201.
27. Spratley MH. An investigation of the adhesion of acrylic resin to dentures. J Prosthet Dent 1987; 58: 389-392.
28. Morrow RM, Matvias FM, Windeler AS, Fuchs RJ. Bonding of plastic teeth to two heat curing denture base resins. J Prosthet Dent 1978; 39: 565-568.
29. Can G, Kansu G. An evaluation of the bond strength of plastic teeth to acrylic denture base materials. Ankara Univ Hekim Fak Derg 1990; 17: 97-101.
30. Cardash HS, Liberman R, Helft M. The effect of retention grooves in acrylic resin teeth on tooth denture base bond. J Prosthet Dent 1986; 55: 526-528.
31. Cunningham JL, Benington IC. An investigation of variables which may affect the bond between plastic teeth and denture base resin. J Dent 1999; 27: 129-135.
32. Chung KH, Chung CY, Chung CY, Chan DCN. Effect of pre-processing surface treatments of acrylic teeth on bonding to the denture base. J Oral Rehabil 2008; 35: 268-275.
33. Akin H, Tugut F, Mutaf B, Akin G, Ozdemir AK. Effect of different surface treatments on tensile bond strength of silicone-based soft denture liner. Lasers Med Sci 2011; 26: 783-788.
34. Alkurt M, Yeşil Duymuş Z, Gündoğdu M. Effect of repair resin type and surface treatment on the repair strength of heat-polymerized denture base resin. J Prosthet Dent 2014; 111: 71-78.
35. Gundogdu M, Yesil Duymus Z, Alkurt M. Effect of surface treatments on the bond strength of soft denture lining materials to an acrylic resin denture base. J Prosthet Dent 2014; 112: 964-971.