ASDJ
AINSHAMS DENTAL JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
March2023 • Vol. 29

Comparative in-vivo study on the wear resistance of three different denture teeth materials -1-year study

Reham El Sharabasy[1], Mahmoud El Moutassim -bellah El Homossany[2]

Aim: The purpose of this study was to evaluate the wear resistance of three denture teeth materials using the desktop scanner.
Materials and methods: Fifteen completely edentulous patients were selected. All the patients received complete maxillary and mandibular dentures. The patients were divided into three groups: Group I patients received maxillary dentures with modified anatomic cross linked acrylic resin denture teeth, Group II received maxillary dentures with nano-hybrid composite teeth. Group III patients received maxillary dentures with light cured composite occlusal surfaces. All the maxillary dentures of the three groups were scanned using desktop scanner. Each scan was carried out at the baseline, 6 and 12 months. The software was used to compare the scanned dentures by superimposing the STL files.
Results: There was a significant difference between the light cured composite, the acrylic and composite teeth in both intervals. While there was significant difference between the composite and acrylic teeth in 0-12 months period. At (0-6 months) it was found that the mean of wear in denture teeth made from acrylic resin, composite teeth and light cured composite was 46.13, 44.87 and 36.27 µm . At the interval period (0-12 months), the mean of wear of denture teeth made from acrylic resin, composite teeth and light cured composite was 120.27, 92.07 and 64.53 µm and there was statistically significant differences between the groups where ($p<0.001$).
Conclusion: denture teeth modified with light cured composite resin showed the less total wear compared to acrylic and composite denture teeth.

Keywords: denture teeth, nano-hybrid composite, light cured

1. Lecturer of Oral and Maxillofacial prosthodontics Department, Faculty of Dentistry Ain Shams University, Cairo, Egypt.
2. Associate professor of Oral and Maxillofacial prosthodontics Department, Faculty of Dentistry Ain Shams University, Cairo, Egypt.
Corresponding author: Reham El Sharabasy, email: rehamsharabasy@hotmail.com

Introduction

When treating patients with dentures, it's crucial to take into account the prosthetic teeth's resistance to wear. Excessive wear on the occlusal surfaces of the teeth can result in a decrease in masticatory effectiveness, poor aesthetics, and a reduction in the vertical dimensions of the occlusion.(1)

The majority of artificial teeth are made of (poly methyl methacrylate). However, some producers incorporated silicon dioxide as an inorganic filler to increase abrasion resistance.(2) In a similar vein, inorganic filler particles may be added to a urethane dimethacrylate matrix to make artificial resin teeth.(2) Interpenetrating resin networks and double cross-linking were used in the development of cross-linked acrylic resin teeth, which have been introduced to improve wear resistance.(3,4)

The producers created microfilled and nanofilled teeth to show off outstanding cosmetic and mechanical qualities. Composite resin artificial teeth were created in the 1980s with the goal of having better wear resistance than acrylic resin teeth and being less abrasive to the natural dentition than ceramic teeth. (5,6) The degree of tooth wear varies among individuals in clinical situations. Wear is the gradual decomposition of material brought on by the friction of moving surfaces. The term wear is used to describe a mixture of abrasion, attrition, fatigue wear, and erosion.(7) The mouth cavity is subject to a variety of wear processes, such as mechanical force contact, pH, temperature, eating patterns, and occlusal force.(8)

To compare the wear resistance of prosthetic teeth, several research have been done. Feldspathic ceramic, nano-filled composite resin, experimental acrylic resin with UDMA/PMMA, and IPN acrylic resin teeth were all put to the test for wear resistance by Ghazal and Kern. They discovered that composite teeth outperformed acrylic teeth in terms of wear resistance. Composite teeth with nanofillers wore out more quickly in the same trial than composite teeth with conventional microfillers.(9)

Nano-composite denture teeth were created to address the concerns with staining, wear resistance, and polishing. (10) Several investigations found that nano-composites are more resistant to wear than IPN, DCL, and uncross-linked acrylic denture teeth.(11,12) In 2009, Ivoclar Vivadent introduced new nanohybrid composite denture teeth (SR Phonares) to the market. The novel nano-hybrid composite is made up of UDMA matrix, three distinct fillers, and PMMA clusters that have been strategically placed throughout the structure. To enhance the matrix and improve the material's hardness and wear resistance, inorganic densified silanized SiO2 was utilized. To reinforce the composite structure and help reduce wear on the opposing teeth, silanized SiO2 nanoparticle was utilized. DMA polymer with an inorganically filled DMA polymer was employed to reduce shrinkage stress during polymerization. (13)

It may be less necessary to employ other lengthy procedures if visible light-cured composite resins are used to replace lost or broken denture teeth. It is used to repair missing or damaged denture teeth, make artificial teeth match nearby teeth, reconstruct abraded surfaces on artificial teeth, and replace broken or lost denture teeth (14-16) The strength of the link between the two materials determines how well the maneuver may be executed. (14,17) The literature review found few investigations on the bonding of acrylic resin with light-cured composite resins.(18,19) The thickness of composite resin for denture repair has not been widely studied. As a material for repairing artificial teeth, they focused more on the sort of surface treatment than the composite thickness. (18) Swift et al. demonstrated the

utilization of composites with a 2.5mm thickness.[20] Denture teeth were attached with 4mm thick cold-cured acrylic resins. This was accomplished in two steps of 2 mm each. On the acrylic resin teeth, a bonding zone with an estimated depth of 1 to 1.5 mm was visible. The effectiveness of bonding in different areas of the tooth may depend on the degree of resin molecule cross-linking as well as resin structure.[18] Caswell and Norling's investigation showed such bonding variability for specific brands of prosthetic teeth. [21]

Steel reference balls affixed to the denture base and a dial gauge were used in the 1970s to assess denture wear. The amount of wear was measured using calipers, stereophotogrammetry [22], reflex microscopy [23], computerized coordinate measurement devices, and triangulation laser sensors.[24,25] Another study compared the vertical and volumetric loss of wear facets determined by a laser scanner, a mechanical sensor, and an optical sensor using monochromatic aberration.[26] But compared to the optical sensor, the mechanical sensor recorded larger volumetric loss values and lower vertical loss values. A laser scanner was used in earlier investigations to quantify wear on artificial teeth.[27,28]

One study suggested that wear analysis might be restricted to posterior teeth.[28] No variations in total wear were detected in a three-year clinical evaluation of various denture tooth materials based on cuspal structure, tooth material, preferred chewing side, or gender. [24] In contrast, mandibular teeth in second molars and maxillary teeth in first molars both experienced accelerated tooth deterioration. Confirming laboratory results with clinical trials on denture tooth material wear may be challenging due to high inter-individual variability. Therefore, the purpose of this randomized study was to compare and clinically assess the wear resistance of various denture teeth materials utilizing digital technology. This study's null hypothesis was that there was no difference between acrylic, composite or light-cured composite artificial denture teeth.

Materials and methods

1-Patients enrollment:

Forty-five completely edentulous patients were selected from the outpatient clinic of Removable Prosthodontic Department, Faculty of Dentistry, Beni-Suef university. The age of the selected patients ranged from 45 up to 60 years. Inclusion criteria included: edentulous subjects with indication for full denture construction. Patients exhibiting skeletal Angle's class-I maxillo-mandibular relationship, patients without any history of abnormal habits or neuro motor disorder, and patients without any temporomandibular joint disorders were included in the study. Subjects with allergy against ingredients of the denture base material, subjects from which no compliance can be expected, patients with history of bruxism were excluded from the trial

All of the patients in the study received full maxillary and mandibular dentures, which were made in accordance with standard prosthetic denture treatment protocols. The teeth were arranged in accordance with the lingualised occlusal concept. According to the material of the artificial teeth used, the patients were randomly divided according to a computer-generated randomization schedule into three groups equal in number and gender: Group I patients received complete maxillary and mandibular dentures with modified anatomic cross-linked acrylic resin denture teeth (Acry Rock V teeth; Ruthenium group) while Group II received maxillary and mandibular complete dentures with nano-hybrid composite teeth for the maxillary dentures (SR Phonares II Typ, Ivoclar Vivadent, Liechtenstein). Patients of Group III

received a set of maxillary and mandibular complete dentures after the modification of the occlusal surfaces of the acrylic resin denture teeth of the maxillary dentures with light cured composite. For allocation of the participants a randomization sequence using forty-five small papers written on one third of them A for acrylic teeth and C for composite teeth and VLC for light cured teeth and put in sealed similar envelops. Where at time of try in, blindly one of the papers was drawn to enroll this participant in the selected group. At time of delivery clinical remounting was made, and necessary occlusal adjustments were performed.

II- Preparation of composite occlusal surfaces of acrylic denture teeth:

For all the patients of Group III, after laboratory remounting procedure, finishing and polishing, clear acrylic stents were fabricated on the dentures. All the posterior teeth of the maxillary dentures were ground to approximately 2 mm depth. The teeth were conditioned by sandblasting at a pressure of 2-3 bars using 110 µm aluminum oxide. Then the surfaces of the posterior teeth were wetted with Visio.link (Visio.link, bredent. Germany) using a brush and polymerized subsequently in the light polymerization unite for 90 seconds. A layer of composite material (Tetric N-ceram, Ivoclar Vivadent, Liechtenstein) was added to the occlusal surfaces of the teeth and then the stents were placed back onto the dentures. The composite was then polymerized using light curing machine. Fig (1a, b). The composite was then finished and polished following the usual manner.

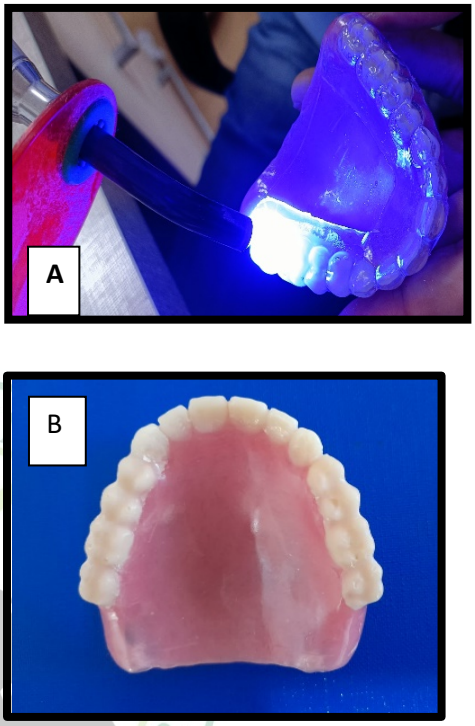

Fig.1: (a) curing of composite occlusal surfaces of denture teeth (b) maxillary denture with finished composite occlusal surfaces

III- Scanning the dentures:

All the maxillary dentures of the three groups after performing the necessary occlusal adjustments (after an occlusal adjustment period of 1 week) and before being delivered to the patients, were scanned using desktop scanner (Zirkonzhan, Italy). Each scan for each individual maxillary denture for each participant of the three included groups was carried out at the baseline (i.e. after occlusal adjustments), 6 months (after the baseline), 12 months (after the baseline). All denture teeth were examined for calculus, stains, or foreign debris before being cleaned with an ultrasonic cleaning system if necessary. The data obtained were then collected to be used for comparison using (Geomagic control X v2018.0.0, 3D Systems Inc, Rock Hill, SC, USA). The software was used to compare the scanning of maxillary dentures at the baseline

with the scanning at 6 months, 12 months follow up by superimposing the images. Fig. (2)

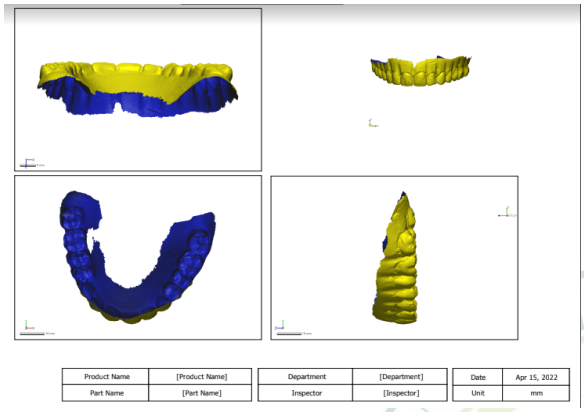

Fig. 2: superimposed images of scanned denture at different follow up periods using Geomagic software

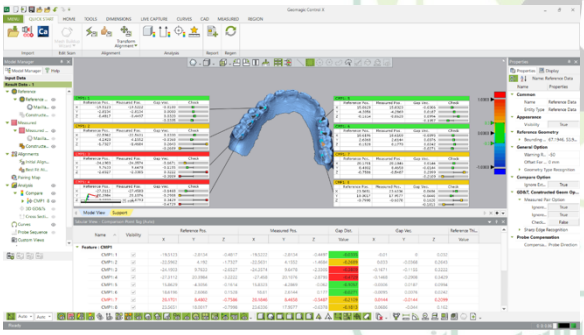

Fig.3: Measurements of tooth wear at different cusps

Results

Statistical methods:

The statistical package for the social sciences (SPSS) version 28 was used to code and enter the data (IBM Corp., Armonk, NY, USA). The mean and standard deviation were used to summarize the data. The analysis of variance (ANOVA) with multiple comparisons post hoc test was used to compare groups (Chan, 2003). P-values less than 0.05 were considered as statistically significant.

1-Effect of different tooth materials on wear at First premolar, Second premolar and First molar during the first interval period (0-6 months)

At the interval period (0-6 months) it was found that The calculated mean of wear at the first premolar ,second premolar and first molar fabricated from acrylic resin was 43.60,47.40 and 47.40 µm .The calculated mean of wear at the first premolar ,second premolar and first molar fabricated from light cured composite was 42.20 ,46.20 and 46.20 µm .The calculated mean of wear at the first premolar, second premolar and first molar fabricated from nano-composite was 28.00 ,39.60 and 41.20 µm , significant differences between the groups at the first interval period where ($p<0.001$) as shown in Table (1) .Light cured composite was statistically significant ($P<0.001$) against both acrylic and composite denture teeth as shown in Table (2).

Table (1): The mean, standard deviation (SD) values of wear of different groups at the first premolar, second premolar and first molar during the period (0-6) months:

0-6 month	Acrylic teeth		Composite teeth		Light cured Composite		P value
	Mean	SD	Mean	SD	Mean	SD	
First premolar	43.60	2.19	42.20	1.92	28.00	2.74	< 0.001
Second premolar	47.40	2.30	46.20	1.30	39.60	0.55	< 0.001
First molar	47.40	2.30	46.20	1.30	41.20	1.30	< 0.001

Table (2) Level of significance of different materials in each tooth group during the period (0-6) months:

First premolar	Acrylic teeth	Composite teeth	Light cured Composite
Acrylic teeth		1.000	< 0.001
Composite teeth	1.000		< 0.001
LC composite	< 0.001	< 0.001	
Second premolar			
Acrylic teeth		0.742	< 0.001
Composite teeth	0.742		< 0.001
LC composite	< 0.001	< 0.001	
First molar			
Acrylic teeth		0.861	< 0.001
Composite teeth	0.861		0.002
LC composite	< 0.001	0.002	

2-Effect of different tooth materials on wear at First premolar, Second premolar and First molar during the interval period (0-12 months)

At the interval period (0-12 months) it was found that the calculated mean of wear

at the first premolar, second premolar and first molar fabricated from acrylic resin was 102.00,124.00,134.80 µm when compared to the calculated mean of wear fabricated from composite 88.20,91.60 and 96.40 µm and the calculated mean of wear fabricated from Light cured composite 59.00,65.40 and 69.20 µm , significant differences between the groups at the first interval period where ($p<0.001$) as shown in Table (3) . Light cured composite was statistically significant $P<0.001$ against both acrylic and composite denture teeth. Acrylic teeth were statistically significant ($P<0.001$) against the composite teeth as shown in Table (4).

Table (3): The mean, standard deviation (SD) values of wear of different groups at the first premolar, second premolar and first molar during the period (0-12) months:

0-12 months	Acrylic teeth		Composite teeth		Light cured Composite		P value
	Mean	SD	Mean	SD	Mean	SD	
first premolar	102.00	4.47	88.20	2.05	59.00	2.24	< 0.001
Second premolar	124.00	26.08	91.60	8.26	65.40	5.86	< 0.001
First molar	134.80	18.91	96.40	10.71	69.20	0.84	< 0.001

Table (4) Level of significance of different denture teeth materials in each tooth group during the period (0-12) months:

First premolar	Acrylic teeth	Composite teeth	Light cured Composite
Acrylic teeth		< 0.001	< 0.001
Composite teeth	< 0.001		< 0.001
LC composite	< 0.001	< 0.001	
Second premolar			
Acrylic teeth		0.024	< 0.001
Composite teeth	< 0.001		0.074
LC composite	< 0.001	0.074	
First molar			
Acrylic teeth		< 0.001	< 0.001
Composite teeth	< 0.001		0.015
LC composite	< 0.001	0.015	

3- Overall wear during the t interval period (0-6,0-12 months)

At the interval period (0-6 months) it was found that the calculated mean of wear of denture teeth made from acrylic resin, composite teeth and light cured composite was 46.13Um, 44.87 and 36.27 µm respectively .Meanwhile, at the interval period (0-12 months) it was found that the calculated mean of wear of denture teeth made from acrylic resin, composite teeth and light cured composite was 120.27, 92.07 and 64.53 µm respectively and there was statistical significant differences between the groups where ($p<0.001$) as shown in Table (5),Fig (4) and Fig(5).

Table (5) The mean, standard deviation (SD) values of wear of overall wear different groups

Period	Acrylic teeth		Composite teeth		Light cured composite		P valu
	Mean	SD	Mean	SD	Mean	SD	
0-6 months	46.13	1.59	44.87	1.12	36.27	0.8	< 0.00
0-12 months	120.27	12.36	92.07	1.79	64.53	1.76	< 0.00

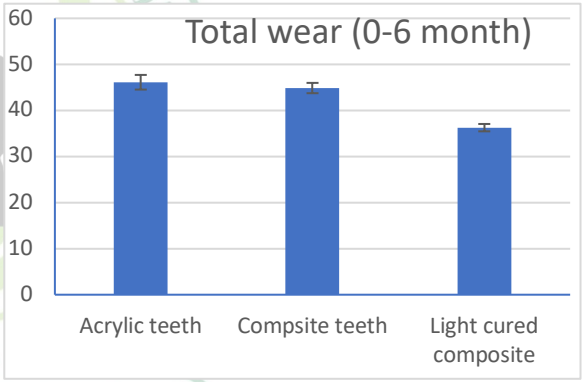

Fig. (4): Bar graph comparing total wear of different denture teeth materials during 0-6 months interval

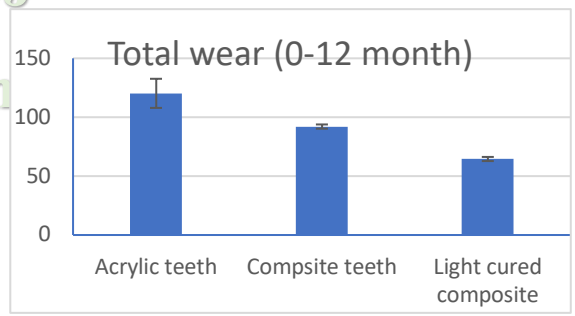

Fig (5) Bar graph comparing total wear of different denture teeth materials during 0-12 months interval

Discussion

The null hypothesis was rejected in this study, as there was statistically

significant difference between the three groups.

One study found that among complete denture wearers, the vertical loss from composite resin denture teeth rose steadily over the course of 24 months, reaching a median vertical loss of 226 (171) µm after that time. These results can help with the interpretation of upcoming in vitro wear studies because they are consistent with the results of two earlier clinical trials that employed the same technique to measure wear. [31,28] The posterior denture teeth experienced a median vertical loss of 121-221 µm after a year of use, according to Schmid-Schwap et al. [28] Another study found that after six months, full dentures had an average posterior tooth wear of 19 µm.[31] Less vertical loss was seen in earlier investigations of denture tooth wear, with annual wear of 58-85 [32] and 90 µm. [33]

Through the use of technology and applications that are simple to use and that can be quickly added to the current arsenal of a typical clinical practice, this work illustrates an accurate and effective technique to assess denture teeth wear. It is essentially a superimposition technique, and depending on what the doctor needs, the result can be seen in all three dimensions and measured as either a linear or volumetric number. Since the reference area selection is simple and the matching procedure is totally automated, the operator-effect on the measured outcomes is anticipated to be reduced.

We assessed the maxillary dentures in our study. The jaw considerably affected the rate of wear, according to other studies on people who wore complete dentures. It was found that the mandibular denture teeth wore down more slowly than the maxillary denture teeth. [24,28]

There is debate in the research on the impact of tooth type—molars vs. premolars—on wear resistance.[28, 34] It was shown that volumetric wear varied depending on the kind of tooth (molars, premolars, incisors, and canines.[28] Clinical studies on enamel and fixed polymer crowns showed that both had a significant impact on wear, with premolar wear being greater than molar wear. [35,36] These conflicting results may be explained by differences in eating behaviors, biting forces, and nutritional choices between edentulous and dentulous individuals. [37] A recurring theme in all the clinical research previously covered is the significant impact of the individual patient on wear. [32, 33, 28]

Additionally, our study found that the wear varied considerably, which was possibly due to subject variance. The degree of wear on the denture teeth was measured using a desktop scanner because of its accuracy and usefulness in past investigations.[28] These days, desktop scanners are thought to be the most accurate, successful, and practical method for conducting clinical wear analysis.[38]

The majority of clinical wear studies, including our own, have found that there is significant patient variation in the occlusal wear of denture teeth. One hypothesis is that mechanical forces (like bruxism) and other factors combine intricately to cause wear processes in the oral cavity (e.g., erosion, corrosion processes, and nutritional habits). On the other hand, it is questionable whether patient-related factors have an impact on how much wear has occurred.[9]

According to a study by Stober et al., who evaluated various composite and acrylic teeth and found similar results, the overall wear of acrylic teeth in our study was 120.27 µm, whereas the wear of nanofilled composite resin denture teeth was 92.07 µm.[39] Lack of periodontal receptors may also explain why edentulous subjects experience less wear. In this regard, it is important to emphasize that opposing surface roughness significantly affects wear results.[40]

Today, laboratories use light, temperature, humidity, pressure, and time control systems to produce indirect composite restorations with a higher degree of polymerization, lower polymerization shrinkage stresses, and improved mechanical characteristics.(41)

The improvement of composite resins' wear resistance with the inclusion of suitable fillers with particle sizes less than 0.1 µm was previously described by Bayne et al (42) According to a study on wear and vertical loss of various composite resin restorations, the average total wear of composite restorations placed on acrylic teeth is 64.53 µm after one year. (43) The annual wear of composite resin as determined by clinical testing differed significantly between trials. According to one study, a class II posterior composite resin restoration typically had wear of 205 µm after a year. (44)

Conclusion

Within limitations of this study, it can be concluded that the denture teeth modified with light cured composite resin showed less total wear compared to acrylic and composite denture teeth.

Recommendation

In the future studies, it is recommended to include larger study sample and longer follow-up period.

References

1. Tsujimoto A, Barkmeier WW, Fischer NG, Nojiri K, Nagura Y, Takamizawa T, Latta MA, Miazaki M. Wear of resin composites: Current insights into underlying mechanisms, evaluation methods and influential factors. Japanese Dental Science Review. 2018;54(2):76-87.
2. Stober T, Lutz T, Gilde H, Rammelsberg P. Wear of resin denture teeth by two-body contact. Dent Mater. 2006;22(3):243–9.
3. Ramos GF, Pereira GKR, Amaral M, Valandro LF, Bottino MA. Effect of grinding and heat treatment on the mechanical behavior of zirconia ceramic. Braz Oral Res. 2016; (1):30
4. Amaral M, Valandro LF, Bottino MA, Souza ROA. Low-temperature degradation of a Y-TZP ceramic after surface treatments. J Biomed Mater Res - Part B Appl Biomater. 2013;101(8):1387–92.
5. Zeng J, Sato Y, Ohkubo C, Hosoi T. In vitro wear resistance of three types of composite resin denture teeth. J Prosthet Dent. 2005;94(5):453–7.
6. Abe Y, Sato Y, Taji T, Akagawa Y, Lambrechts P, Vanherle G. An in vitro wear study of posterior denture tooth materials on human enamel. J Oral Rehabil. 2001;28(5):407–12.
7. Mair LH, Stolarski TA, Vowles RW, Lloyd CH. Wear: mechanisms, manifestations and measurement. Report of a workshop. Journal of dentistry. 1996 ;24(1-2):141-8.
8. Kern M, Strub JR, Lü XY. Wear of composite resin veneering materials in a dual-axis chewing simulator. J Oral Rehabil. 1999;26(5):372–8.
9. Heintze SD, Zellweger G, Sbicego S, Rousson V, Muñoz-Viveros C, Stober T. Wear of two denture teeth materials in vivo - 2-year results. Dent Mater. 2013;29(9):191-204.
10. Zhou ZR, Zheng J. Tribology of dental materials: A review. J. Phys. D: Appl. Phys. 2008;41(11): 113001
11. Heintze SD, Faouzi M, Rousson V, Özcan M. Correlation of wear in vivo and six laboratory wear methods. Dent Mater. 2012;28(9):961–73.
12. Lambrechts P, Debels E, Van Landuyt K, Peumans M, Van Meerbeek B. How to simulate wear?. Overview of existing methods. Dent Mater. 2006;22(8):693–701.
13. Habib E, Wang R, Wang Y, Zhu M, Zhu XX. Inorganic fillers for dental resin composites: present and future. ACS biomaterials science & engineering. 2016;2(1):1-11.
14. Muhsin SA. Bond Strength of Repaired Acrylic Denture Teeth Using Visible Light Cure Composite Resin. Open Dent J. 2017;11(1):57–64.
15. Weiner S, Krause AS, Nicholas W. Esthetic modification of removable partial denture teeth with light-cured composites. J Prosthet Dent. 1987;57(3):381–4.
16. Vergani CE, Giampaolo ET, Cucci ALM. Composite occlusal surfaces for acrylic resin denture teeth. J Prosthet Dent. 1997;77(3):328–31.
17. Chatterjee N, Gupta TK, Banerjee A. A study on effect of surface treatments on the shear bond strength between composite resin and acrylic resin denture teeth. J Indian Prosthodont Soc. 2011;11(1):20–5.
18. Papazoglou E, Vasilas AI. Shear bond strengths for composite and autopolymerized acrylic resins bonded to acrylic resin denture teeth. J Prosthet Dent. 1999;82(5):573–8.
19. Helal MA, Al-Gazzar AE, Abas M, Akhtar S, Gad MM, Al-Thobity AM. Comparative Effect of

Different Surface Treatments on the Shear Bond Strength of Two Types of Artificial Teeth Bonded To Two Types of Denture Base Resins. J Prosthodont. 2022, 31.5: 427-433
20. Swift EJ, LeValley BD, Boyer DB. Evaluation of new methods for composite repair. Dent Mater. 1992;8(6):362–5.
21. Wayne Caswell C, Norling BK. Comparative study of the bond strengths of three abrasion-resistant plastic denture teeth bonded to a cross-linked and a grafted, cross-linked denture base material. J Prosthet Dent. 1986;55(6):701–8.
22. Ogle RE, Ortman LF. Measuring wear of artificial teeth with stereophotography: Part I. J Prosthet Dent. 1985;53(6):807–12.
23. Adams LP, Joosle CH, Thomas CJ. An indirect in vivo method for quantification of wear of denture teeth. Dent Mater. 1989;5(1):31–4.
24. Ogle RE, Davis EL. Clinical wear study of three commercially available artificial tooth materials: Thirty-six month results. J Prosthet Dent. 1998;79(2):145–51.
25. Mehl A, Gloger W, Kunzelmann KH, Hickel R. A new optical 3-D device for the detection of wear. J Dent Res. 1997;76(11):1799–807.
26. Heintze SD, Cavalleri A, Forjanic M, Zellweger G, Rousson V. A comparison of three different methods for the quantification of the in vitro wear of dental materials. Dent Mater. 2006;22(11):1051–62.
27. Stober T, Geiger A, Rues S, Dreyhaupt J, Rammelsberg P, Ohlmann B. Factors affecting wear of composite resin denture teeth-24-month results from a clinical study. Clin Oral Investig. 2012;16(2):413–20.
28. Schmid-Schwap M, Rousson V, Vornwagner K, Heintze SD. Wear of two artificial tooth materials in vivo: A 12-month pilot study. J Prosthet Dent. 2009;102(2):104–14.
29. Mahalick JA, Knap FJ, Weiter EJ. Occusal wear in prosthodontics. J Am Dent Assoc. 1971;82(1):154–9.
30. Reis KR, Bonfante G, Pegoraro LF, Conti PCR, De Oliveira PCG, Kaizer OB. In vitro wear resistance of three types of polymethyl methacrylate denture teeth. J Appl Oral Sci. 2008;16(3):176–80.
31. Ohlmann B, Rohstock K, Kugler J, Gilde H, Dreyhaupt J, Stober T. Influences on clinical wear of acrylic denture teeth: A pilot study. Int J Prosthodont. 2007;20(5):496–8.
32. Ogle RE, David LJ, Ortman HR. Clinical wear study of a new tooth material: Part II. J Prosthet Dent. 1985;54(1):67–75.
33. Lindquist TJ, Ogle RE, Davis EL. Twelve-month results of a clinical wear study of three artificial tooth materials. J Prosthet Dent. 1995;74(2):156–61.
34. Stober T, Dreyhaupt J, Lehnung U RP. Occlusal wear of metal-free ceramic-filled polymer crowns after 2 years in service. Int J Prosthodont. 2008;21(2):161–5.
35. Stober T, Dent M, Nat R. Occlusal Wear of Metal-Free Ceramic-Filled Polymer Crowns. Int J Prosthodont., 2008, 21(2): 161-5.
36. Lambrechts P, Braem M, Vuylsteke-Wauters M, Vanherle G. Quantitative in vivo Wear of Human Enamel. J Dent Res. 1989, 68(12): 1752-54
37. Moriya Y, Tuchida K, Moriya Y, Sawada T, Koga J, Sato J, Nishikawa M, Takizawa T, Uematsu H, Ozaki T, Gionhaku N. The influence of craniofacial form on bite force and EMG activity of masticatory muscles. VIII-1. Bite force of complete denture wearers. J Oral Sci. 1999, 41(1): 19-27
38. Perry R, Kugel G, Kunzelmann KH, Flessa HP, Estafan D. Composite restoration wear analysis: Conventional methods vs. Three-dimensional laser 2digitizer. J Am Dent Assoc. 2000;131(10):1472–7.
39. Stober T, Henninger M, Schmitter M, Pritsch M, Rammelsberg P. Three-body wear of resin denture teeth with and without nanofillers. J Prosthet Dent. 2010;103(2):108-117.
40. Ghazal M, Kern M. The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. J Prosthet Dent 2009;101:342–9
41. Tanoue N, Murakami M, Koizumi H, Atsuta M, Matsumura H. Depth of cure and hardness of an indirectcomposite polymerized with three laboratory curing units. J Oral Sci 2007;49:25-29.
42. Bayne SC, Taylor DF, Heymann HO. Protection hypothesis for composite wear. Dent Mater. 1992;8:305–309.
43. Palaniappan, S., Elsen, L., Lijnen, I., Peumans, M., Van Meerbeek, B. and Lambrechts, P.Three-year randomised clinical trial to evaluate the clinical performance, quantitative and qualitative wear patterns of hybrid composite restorations. Clin Oral Invest. 2010, 14(4): 441-458
44. Pesun IJ, Olson AK, Hodges JS, Anderson GC. In vivo evaluation of the surface of posterior resin composite restorations: a pilot study. J Prosthet Dent 2000; 84: 353–359.