

## Original Article

# A comparative evaluation of wear resistance of three types of artificial acrylic teeth after removing the glaze layer

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## ABSTRACT

**Background:** The posterior denture teeth wear faster than the anterior teeth, which can result in occlusal interferences, loss of vertical dimension of occlusion, greater stress accumulation in the anterior region, and higher ridge resorption. This study aimed to compare the wear resistance of three types of artificial acrylic teeth before and after removing the glaze layer.

**Materials and Methods:** This *in vitro* study compared three types of artificial acrylic teeth, namely, Finex (F), SR Orthotyp DCL (S), and Vita Physiodents (V) in six groups ( $n = 10$ ). Half of the artificial teeth of each brand underwent 0.5-mm buccal reduction to remove the glaze layer (groups FC, SC, and VC). The teeth were thermocycled and placed in a chewing simulator. The teeth with and without the glaze layer were weighed before and after the wear test. The data were analyzed using ANCOVA (the level of significance was 0.05).

**Results:** The weight reduction (indicative of wear) was  $0.03 \pm 0.02$  and  $0.12 \pm 0.03$  mg in Groups S and SC,  $0.03 \pm 0.02$  and  $0.25 \pm 0.04$  mg in Groups V and VC, and  $0.11 \pm 0.15$  and  $0.28 \pm 0.1$  mg in groups F and FC, respectively. Removing the glaze layer ( $P < 0.01$ ), type and brand of acrylic tooth ( $P < 0.01$ ), and the baseline weight of artificial teeth ( $P < 0.01$ ) had significant effects on wear resistance of artificial teeth.

**Conclusion:** The wear of artificial teeth was greater after removing the glaze layer, and the magnitude of wear was also significantly different among the three brands. The group FC showed maximum wear while the groups S and V showed minimum wear.

**Key Words:** Artificial, dental restoration wear, polymethyl methacrylate, tooth

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## INTRODUCTION

The materials used for the fabrication of artificial teeth such as the acrylic resins or porcelain have greatly evolved over time; however, an ideal material has not yet been introduced to meet all the prosthetic and esthetic needs of patients.<sup>[1]</sup> The physical and mechanical properties of artificial teeth materials such as color stability, biocompatibility, compressive and tensile strengths, esthetic appearance, hardness,

wear resistance, bonding ability to the denture base, minimal deformation, and stability of surface polish after baking play fundamental roles in achieving a successful prosthetic treatment. If these requirements are not met, complications such as impaired mastication, loss of vertical dimension of occlusion (VDO), impairment of occlusal relationship, oral tissue injury, resorption of the anterior part of the

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ridge, temporomandibular disorders, or loss of shape and esthetic appearance of the teeth may occur.<sup>[2,3]</sup>

The main drawback of artificial resin teeth is the fast wear of the posterior tooth surfaces and consequent change in VDO. It also adversely affects the occlusal relationship, the pressure applied to the oral mucosa and the underlying bone, and the esthetic appearance of the teeth. Several factors affect the wear of acrylic teeth such as the magnitude of applied load to the surfaces, the relative speed of movement of surfaces, surface characteristics, and material composition.<sup>[4]</sup>

Older types of artificial teeth had two distinct layers of enamel and dentin.<sup>[5]</sup> However, the newer types do not follow this classification and may have an additional middle layer between the enamel part and the base layer (dentin). Each layer has different characteristics in terms of hardness and monomer dispersion.<sup>[6]</sup> Moreover, the outermost surface or the enamel layer of artificial teeth is often removed due to some reasons such as wear due to mastication or occlusal adjustments by dental clinicians. In complete denture treatment, the mean increase in the height of the incisal guidance pin after the acrylic baking is 0–1.49 mm.<sup>[7]</sup> The abovementioned outermost layer is often removed by selective elimination of occlusal interferences in the laboratory or during clinical remounting to achieve maximum intercuspation. This would lead to exposure of the underlying layer of artificial teeth.<sup>[5]</sup>

In denture fabrication, teeth with higher wear resistance should be selected, unless for some certain cases. In some cases, however, teeth with lower wear resistance are recommended to preserve the health of oral tissues. Such teeth are indicated for patients with lower masticatory forces or those under ridge augmentation treatment.<sup>[8]</sup>

Considering the gap of information regarding the wear resistance of artificial teeth and the significance of this topic, this *in vitro* study aimed to compare the wear resistance of three types of artificial teeth. The null hypothesis was that there would be no significant difference in wear resistance of different types of artificial acrylic teeth.

## MATERIALS AND METHODS

### Sample preparation

This *in vitro* experimental study evaluated three types of artificial acrylic teeth, namely, Finex (BetaDent, Iran), SR Orthotyp DCL (Ivoclar Vivadent AG,

Liechtenstein), and Vita Physiodens (VITA Zahnfabrik, Germany) [Table 1]. The right and left artificial first molar acrylic teeth were randomly divided into six groups ( $n = 10$ ). The first three groups included the Finex (F), SR Orthotyp DCL (S), and the Vita Physiodens (V) groups. Each group included 10 artificial first molar teeth with an intact glaze layer. The second three groups were the same brands of artificial teeth with their glaze layer removed, referred to as the FC, SC, and VC groups, each including 10 artificial first molars with 0.5-mm buccal reduction to remove the glaze layer. Buccal reduction was performed using a diamond bur (Jota, Switzerland) and high-speed hand-piece (NSK Pana-Max, Japan). First, a positioning jig of silicone putty (Duosil™, SHERA Werkstoff-Technologie, Germany) was made according to the right or left molar tooth which covers the entire buccal surface. In the next step, a stainless steel mold was placed on the set of teeth, and the positioning putty, and then the self-cure acrylic resin (Acropars, Marlic, Iran) was injected. Using this positioning jig, all samples were mounted under uniform and standard conditions [Figure 1].

### Thermocycling

**Table 1: Materials used in this study**

Brand name	Composition	Abbreviation	Manufacturer
Finex	UDMA, inorganic filler	F, FC	Beta Dent, Iran
SR Orthotyp DCL	PMMA, double cross linked	S, SC	Ivoclar Vivadent AG, Liechtenstein
Vita Physiodens	PMMA, inorganic micro-particle filler	V, VC	VITA Zahnfabrik, Germany

F: Finex teeth with intact surface; FC: Finex teeth with 0.5-mm buccal reduction; S: SR Orthotyp DCL teeth with intact surface; SC: SR Orthotyp DCL teeth with 0.5-mm buccal reduction; V: Vita Physiodens teeth with intact surface; VC: Vita Physiodens® teeth with 0.5-mm buccal reduction



**Figure 1: Mounted samples for placement in chewing simulator.**

The samples then underwent thermal cycles in a thermocycler (MSCT-3; Convel) for 1 week, 3 weeks, and 6 weeks between 5°C and 55°C with a dwell time of 30 s and a transfer time of 10 s to simulate aging. Next, they were placed in an ultrasonic bath (EURONDA, Vicenza, Italy) to eliminate the loose particles. They were then transferred to an oven (LAC1-38 120V, Despatch, USA) and heated at 50°C for 120 min to complete dry. Finally, the teeth were weighed by a digital scale (BL120 Suartorius, Germany) with 0.0001 g accuracy.

### Wear test and weighing the teeth

The teeth were then fixed in a chewing simulator (SD Mechatronic GmbH) to undergo wear in order to simulate the clinical setting [Figure 2]. In each cycle, first a stroke was applied to the surface followed by a back and forth horizontal motion. The applied load was 3 lb at a speed of 130 rpm. The maxillary first molars were used as the abrasive surface in the chewing simulator. Accordingly, the buccal surface of each mandibular first molar was abraded by the buccal surface of a maxillary first molar tooth of the same brand. Each tooth underwent 5000 cycles first, followed by another 5000 cycles (a total of 10,000 cycles). After 5000 cycles of wear, the teeth were placed in an ultrasonic bath for 10 min to

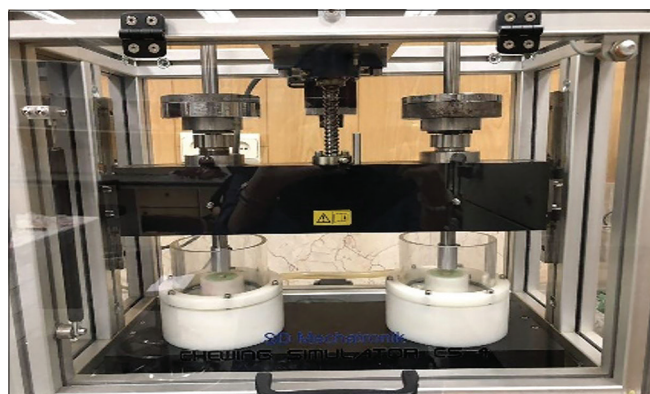


Figure 2: Chewing simulator device.

eliminate the loose particles. Next, they were dried in an oven at 50°C for 120 min. Eventually, the teeth were weighed by a digital scale (BL120 Suartorius, Germany). After the second round of wear, the procedures were repeated. The change in weight of the teeth in each group after wear was then calculated compared with baseline. Eventually, the magnitude of wear in each group was calculated according to the mean change of weight.

### Statistical analysis

The data were analyzed using SPSS version 25. The mean ( $\pm$  standard deviation) weight of artificial acrylic teeth before and after the wear test in the groups with and without the glaze layer, and the mean weight reduction after the wear test (indicative of the magnitude of wear) were calculated and reported. ANCOVA (analysis of covariance) was applied to assess the effect of type (brand) of artificial teeth, removal of glaze layer, and baseline weight of the teeth on the magnitude of wear. Level of significance was set at 0.05 ( $\alpha = 0.05$ ).

## RESULTS

Table 2 shows the mean and standard deviation of the weight of artificial teeth at baseline and after the wear test. Table 3 shows the mean and standard deviation of weight change of artificial teeth after the wear test compared with baseline in the groups.

The maximum mean weight was  $16.34 \pm 2.1$  mg at baseline in group S, and the minimum mean weight was  $14.51 \pm 1.57$  at baseline in group FC. The maximum mean weight was  $16.31 \pm 2.11$  mg after wear test in group S, and the minimum mean weight was  $14.23 \pm 1.54$  mg after wear test in group FC.

According to ANCOVA, presence/absence of the glaze layer ( $P < 0.01$ ), the brand of artificial teeth ( $P < 0.01$ ), and baseline weight of artificial teeth ( $P < 0.01$ ) had significant effects on the

Table 2: Mean $\pm$ standard deviation wear at baseline and after the wear test in different artificial teeth with/without the glaze layer

Group name	Descriptive statistics	Baseline weight (mg)	Weight after wear test (mg)	Magnitude of wear
S	Mean $\pm$ SD	16.34 $\pm$ 2.1	16.31 $\pm$ 2.11	0.03
SC	Mean $\pm$ SD	16.24 $\pm$ 2.11	16.12 $\pm$ 2.1	0.12
V	Mean $\pm$ SD	15.86 $\pm$ 1.29	15.82 $\pm$ 1.28	0.03
VC	Mean $\pm$ SD	15.68 $\pm$ 1.24	15.43 $\pm$ 1.24	0.25
F	Mean $\pm$ SD	14.8 $\pm$ 1.85	14.69 $\pm$ 1.84	0.11
FC	Mean $\pm$ SD	14.51 $\pm$ 1.57	14.23 $\pm$ 1.54	0.28

S: SR Orthotyp DCL teeth with intact surface; SC: SR Orthotyp DCL teeth with 0.5-mm buccal reduction; V: Vita Physiodens teeth with intact surface; VC: Vita Physiodens® teeth with 0.5-mm buccal reduction; F: Finex teeth with intact surface; FC: Finex teeth with 0.5-mm buccal reduction; SD: Standard deviation

magnitude of wear (wear resistance) of artificial teeth [Table 4]. The wear resistance of artificial teeth with/without the glaze layer was significantly different ( $P < 0.01$ ). In all artificial teeth, the magnitude of wear was significantly greater after removal of the glaze layer.

## DISCUSSION

The current results revealed a significant difference in wear resistance of artificial teeth with and without the glaze layer, such that the magnitude of wear was higher after removal of the glaze layer in all three tested brands. Furthermore, the magnitude of wear (indicative of wear resistance) was significantly different between the three brands of artificial teeth. Greater wear following removal of the glaze layer is due to decreased cross-linking. Minimum wear was noted in group S, which was probably due to the composition of artificial teeth of this brand. These teeth are made of a polymer matrix and organic fillers that are homogeneously cross-linked. This composition yields excellent stability and high wear resistance. The wear of FC acrylic teeth was higher than that of other groups. Different behaviors of acrylic teeth in this respect can be due to the type and quality of acrylic resin used for the fabrication of artificial teeth. Other influential factors in this regard include the strength

of artificial teeth, their form and shape (e.g. thickness of incisal edge or thickness of body), orientation of teeth mounted in acrylic base, errors in laboratory procedures, density, gaps and porosity of the material, manufacturing precision, and dispersion of polymer in artificial tooth structure.<sup>[9]</sup> On the other hand, simulation of chewing forces and frequency of application of masticatory loads,<sup>[10]</sup> occlusal forces, wear caused by the consumption of different foods and drinks, mechanical properties of the materials,<sup>[11,12]</sup> and some other factors also play a role in this respect. Furthermore, the worn particles remain in the environment and further enhance the process of wear as foreign bodies. However, in this study, the teeth were placed in an ultrasonic bath for 10 min after the first round of wear to eliminate the worn particles.

The type of wear test is an important parameter that can affect the wear behavior of artificial teeth. Although clinical studies provide more valuable information regarding the wear behavior of materials, they require a complex methodology, are costlier, and time-consuming. Thus, *in vitro* studies are more suitable for this purpose. However, *in vitro* studies also have limitations in the simulation of the clinical setting in terms of load application, neuromuscular movements, saliva pH, oral hygiene practice, and the nutritional regimen of patients.

The methods used for assessment of the magnitude of wear in previous studies include estimation of reduction in VDO, weight reduction, and volume reduction. In the present study, the weight reduction method was used for this purpose.<sup>[5,13]</sup> Most researchers have used wear tests with rotational or back and forth movements. However, evidence shows that complex wear tests, despite the greater attention to details, are not significantly different from simple wear tests due to a higher rate of operator errors.<sup>[14]</sup> Since the masticatory cycles in the oral environment range from 5000 to 300,000 cycles per day, 5000–10,000 chewing cycles were applied in this study to simulate the clinical setting.<sup>[15]</sup>

**Table 3: Mean±standard deviation weight change of artificial teeth after the wear test in the six groups (n=10)**

Group name	Mean (mg)±SD
S	0.03±0.02
SC	0.12±0.03
V	0.03±0.02
VC	0.25±0.04
F	0.11±0.15
FC	0.28±0.1

S: SR Orthotyp DCL teeth with intact surface; SC: SR Orthotyp DCL teeth with 0.5-mm buccal reduction; V: Vita Physiodens teeth with intact surface; VC: Vita Physiodens® teeth with 0.5-mm buccal reduction; F: Finex teeth with intact surface; FC: Finex teeth with 0.5-mm buccal reduction; SD: Standard deviation

**Table 4: Results of analysis of covariance to assess the effect of different variables on wear of artificial teeth**

	Mean of sum of squares	Degree of freedom	Sum of squares	F	P
Glaze layer	0.369	1	0.369	56.97	0.01<
Brand of artificial tooth	0.137	2	0.069	10.59	0.01<
Baseline weight	160.055	1	160.055	24,734.747	0.001
Error	0.356	55	0.006		
Total	194.123	59			

On the other hand, two-dimensional wear was used in this study. In other words, no intervening abrasive material was used between the sample and the antagonistic tooth. Since both two-dimensional and three-dimensional wears occur in the oral cavity, the results of this study cannot be perfectly generalized to the clinical setting. The loads applied in the oral environment range from 1 to 3 lb (4.5–13.4 N).<sup>[16]</sup> In this study, a 3 lb load was applied to the teeth at a speed of 130 rpm.

Preis *et al.* evaluated the wear of artificial denture materials and showed that different artificial denture teeth had significant differences in terms of wear *in vitro*. The same observations were reported in this study.<sup>[8]</sup> Also, Kamonwanon *et al.* compared the wear resistance of five types of artificial teeth with those made of modified polymethyl methacrylate, and showed that artificial teeth made of modified polymethyl methacrylate had no significant difference with composite resin artificial teeth, but their wear resistance and surface hardness were higher.<sup>[17]</sup> Hao *et al.* reported that the wear behavior of artificial teeth was variable based on their composition.<sup>[18]</sup> The same results were reported by Suwannaroop *et al.* They reported variable wear resistance of different dental materials.<sup>[5]</sup> Their results were in agreement with our findings. Ghazal *et al.* showed that composite resin teeth experienced greater wear than ceramic teeth, and acrylic resin teeth had less wear than ceramic teeth.<sup>[19]</sup> Difference in wear resistance of artificial acrylic teeth was also observed in this study. Moreover, Reis *et al.* (2008) evaluated the wear of methyl methacrylate denture teeth but found no significant difference in wear between three types of denture teeth and glazed ceramic teeth, which was different from our findings.<sup>[20]</sup> Difference in the results of the studies can be due to different methodologies and use of different denture teeth. Also, Stober *et al.* evaluated the wear resistance of nine acrylic resin denture teeth and showed that different denture materials experienced different magnitudes of wear.<sup>[21]</sup> Munshi *et al.* (2017) found a significant difference in wear resistance of three types of denture teeth.<sup>[22]</sup> Variations in the wear of artificial teeth were also noted in this study, which was in line with their findings.

The composition and type of abrasive material are important parameters affecting the results of studies. Although it may seem that only the hardness of abrasive material has a direct correlation with the degree of abrasion, it appears that aside from

hardness, some other factors such as roughness and fracture resistance or strength of a material also affect its abrasiveness. Moreover, presence/absence of a third material in the environment can also affect the wear resistance. These materials either decrease the wear as a lubricant or serve as an abrasive and accelerate the wear.<sup>[23]</sup> The abrasive surface in this study was the maxillary first molar teeth of the same brands to better simulate the oral clinical setting. The buccal surface of each mandibular first molar was worn by the buccal surface of the maxillary first molar of the same brand.

According to the current results, the wear of Finex, SR Orthotyp DCL, and Vita Physiodens artificial teeth was lower in the presence of the glaze layer. Removal of the glaze layer decreased the resistance of all three groups of artificial teeth to wear caused by the chewing cycles, and enhanced their wear. In the presence of the glaze layer, higher cross-linking increased the wear resistance. This topic has not been evaluated in any previous study to compare our results with.

Ideally, the wear behavior of dental materials and dental restorations should be similar to that of natural enamel. If so, the occlusal interferences caused by the differences in wear resistance of dental materials, restorations, and natural teeth are minimized. In order to choose artificial teeth with minimal wear, dentists should have adequate information about the wear behavior of different types of artificial teeth. In general, due to the limitations of studies on this topic, a definite conclusion regarding the effect of type (brand) of artificial teeth (and particularly their chemical composition) on wear resistance cannot be drawn. It may be assumed that the manufacturing technique and the commercial brand have a greater effect than the composition of artificial teeth on their wear behavior. However, further studies are warranted on different brands of artificial teeth using different clinical and laboratory methods.

## CONCLUSION

According to the current results, presence/absence of the glaze layer ( $P < 0.01$ ), the brand of artificial teeth ( $P < 0.01$ ), and their baseline weight ( $P < 0.01$ ) had significant effects on wear resistance of artificial teeth. The wear of artificial teeth was greater after removing the glaze layer. Furthermore, a significant difference was noted in wear resistance of the three

brands of artificial teeth. Minimum wear was noted in groups SR Orthotyp DCL teeth with intact surface and Vita Physiodens teeth with intact surface while maximum wear was noted in group Finex teeth with 0.5-mm buccal reduction.

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### Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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