

Original Article

## Comparison of Wear Resistance of Hawley and Vacuum Formed Retainers: An in-vitro Study

Moshkelgosha V<sup>a</sup>, Shomali M<sup>b</sup>, Momeni M<sup>c</sup>

<sup>a</sup>Orthodontic Research Center and Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

<sup>b</sup>Orthodontic Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran

<sup>c</sup>Students Research Committee, School of Dentistry, International Branch, Shiraz University of Medical Sciences, Shiraz, Iran.

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#### Corresponding Author:

Masoomeh Momeni

Students Research

Committee, School of

Dentistry, International

Branch, Shiraz University

of Medical Sciences, and

Shiraz, Iran.

Email: [sepidehmomeni91@](mailto:sepidehmomeni91@yahoo.com)

[yahoo.com](mailto:sepidehmomeni91@yahoo.com)

Tel: +98-9173173799

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### Abstract

**Statement of Problem:** As a physical property, wear resistance of the materials used in the fabrication of orthodontic retainers play a significant role in the stability and long term use of the appliances.

**Objectives:** To evaluate the wear resistance of two commonly used materials for orthodontic retainers: Acropars OP, i.e. a polymethyl methacrylate based material, and 3A-GS060, i.e. a polyethylene based material.

**Materials and Methods:** For each material, 30 orthodontic retainers were made according to the manufacturers' instructions and a 30×30×2 mm block was cut out from the mid- palatal area of each retainer. Each specimen underwent 1000 cycles of wear stimulation in a pin on disc machine. The depth of wear of each specimen was measured using a Nano Wizard II atomic force microscope in 3 random points of each specimen's wear trough. The average of these three measurements was calculated and considered as mean value wear depth of each specimen (μm).

**Results:** The mean wear depth was 6.10μm and 2.15μm for 3A-GS060 and Acropars OP groups respectively. Independent t-test showed a significant difference between the two groups ( $p < 0.001$ ). The results show Polymethyl methacrylate base (Acropars) is more wear resistance than the polyethylene based material (3A-GS060).

**Conclusions:** As the higher wear resistance of the fabrication material can improve the retainers' survival time and its cost-effectiveness, VFRs should be avoided in situations that the appliance needs high wear resistance such as bite blocks opposing occlusal forces.

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## Introduction

Orthodontic removable appliances such as bite plates, active plates and retainers are the most commonly made of Polymethyl methacrylate polymer materials. However, two other based materials were recently introduced to orthodontics as thermoplastic appliances: the Essix retainer and the Invisacryl [1]. They have different reported physical characteristics in terms of life span and resistance to wear, fatigue, and fracture [2].

Vacuum formed appliances (VFRs), first introduced by Ponitz in 1971 [3], are more widely used compared to the more traditional Hawley appliances in the fabrication of orthodontic retainers. Vacuum formed appliances have advantages such as higher aesthetics, lower costs, ease of fabrication, and minimal thickness [4,5]. To fabricate a VFR, a vacuum forming machine pulls a thermoplastic plastic sheet onto working / study cast (made by gypsum plaster) and makes a vacuum to adapt the heat-softened plastic sheet to the cast by negative pressure [6].

From the structural aspect, two materials commonly used for VFR are polyethylene polymers and polypropylene polymers. These polymers are different in flexibility, durability, translucency and ability to bond acrylic resin. Polyethylene polymers have the advantages of transparency (aesthetic), beauty and are the choice, when we want to bond acrylic to posterior bite plane [7]. The polypropylene polymers do not have the beauty of the polyethylene polymers but are considered to be more durable and flexible. These benefits of the polyethylene polymer based appliances over the polypropylene polymer appliances have recently been a subject of controversy since some recent studies performed showed that some physical properties of these appliances may be problematic [1,8,9].

Only few published studies have compared the physical properties of VFR materials. In one study, Gardner *et al.* [1] put polyethylene and polypropylene polymer vacuum appliances under cyclic pressure and reported a higher resistance for the polyethylene polymer appliances. Lindauer *et al.* [8] compared the physical properties and survival of the Essix and Hawley appliances in clinical practice and found that in the Essix appliances, cracks appear after the placement during the follow-up period. Campbell *et al.* [9] showed that in a high number of patients (38%) with vacuum formed retainers, the main cause for the replacement was that the appliances had been worn

out. Mai *et al.* [10] conducted a systematic review to compare the VFRs and Hawley appliances; they reported that with respect to changes in inter canine and inter molar widths after orthodontic retention; there was no difference between the appliances used. They also reported that in terms of occlusal contacts, cost effectiveness, patient satisfaction, and survival time, there was insufficient evidence to support the use of VFRs over Hawley retainers.

Among all physical properties, wear resistance is an important physical characteristic. Wear is considered as the removal of material from a solid surface when undergoing mechanical interaction; however, clinical wear is a more complex process [11,12]. The physical characteristics of the material used in the vacuum made appliances play an important role in defining the stability and long term use of them [13,14], also orthodontic retainers which have posterior bite plan usually get mechanical wear because of occlusal contact with teeth. This emphasizes the importance of appropriate comparison between these appliances. Therefore, in this in vitro study there was an attempt to evaluate and make a comparison between the wear resistance in acrylic and VFRs.

## Materials and Methods

A total of sixty 30×30×2 mm blocks of Acropars OP (n = 30), and 3A-GS060 (n = 30) specimens were cut out of the mid-palatal area of premade orthodontic retainers. The retainers were made in the laboratory of Shiraz University of Medical sciences, School of dentistry. Acropars OP (Marlik Co., Iran) is a polymethylmethacrylic polymer used to prepare Hawley appliances, following the manufacturer's instructions. 3A-GS060 (3A Medes, Korea) is a polyethylene polymer used in the preparation of vacuum formed appliances (VFR), using a vacuum forming machine (Biostar, Scheu Inc., Germany). The manufacturer's instructions were followed in vacuum forming of each block (Figure 1-A).

To compare the two types of retainers, we evaluated 30 Acropars OP and 30 3A-GS060 blocks in two groups. For assessing the wear resistance, a Pin-on-disk device (Model TE 79; Phoenix tribology Ltd, Kingsclere, England) was used similar to the method used by Raja *et al.* [7] (Figure 1-B). The samples were secured on a custom made base plate that was moving on a horizontal plane via an electrical motor. Above all, 10 steel rods were holding the antagonist material- a steatite ball

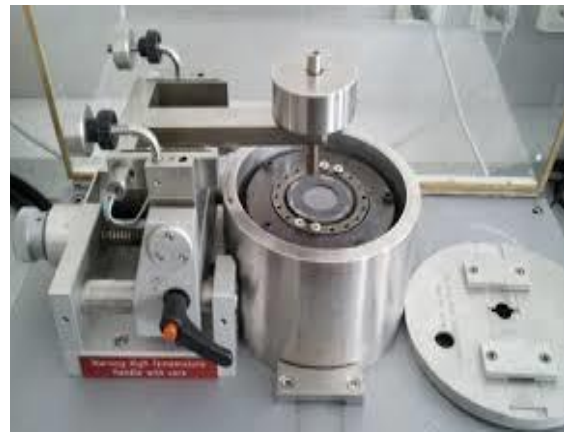


**Figure 1-A:** A vacuum forming machine for which the heating element is acting on the vacuum-formed retainers.

with 8 mm diameter. At the superior end of the rods, there were weights that applied a load of 460 g as the steatite antagonist drops down 3mm and contact our block samples. The duration of contact was 0.2 seconds and each sample was abraded for 1000 cycles. In our study, a cycle was defined as the horizontal cycle of the base plate that was moving from a start point and then reaching its start position again in a circular path with 16 mm diameter. After each abrasion process, a circular abrasion trough was clearly created on each sample, the wear machine was cleaned and lubricated, and new abrasers were used for the next specimen. Then each specimen was washed with distilled water spray to remove and clear all debris from its surfaces.

The wear depth of the trough was measured using a Nano Wizard II atomic force microscope (Figure 2) (JPK Instruments AG, Berlin, Germany). The atomic force microscope (AFM) was used to generate an accurate topographic map of the surface features of each specimen. A three-area wear-depth analysis was used to measure the depth of the trough in 3 points of each specimen. The operator selects three points on 2D topographic images of the trough made by AFM on computer screen (Figure 3-A). 3D topographic images of each marked point were then generated automatically by the accompanying AFM software and the depth of wear in each of three points of the specimen was measured by a computer algorithm (Figure 3-B). The mean of three measurements made on each specimen was used in the statistical analysis as that sample wear depth.

Data were analyzed using the Statistical Software Package for the Social Sciences SPSS, version 18.0, (SPSS Inc., Chicago, IL, USA). Data achieved from the AFM for the two groups were compared using the



**Figure 1-B:** The pin-on-disk machine used to test the wear resistance

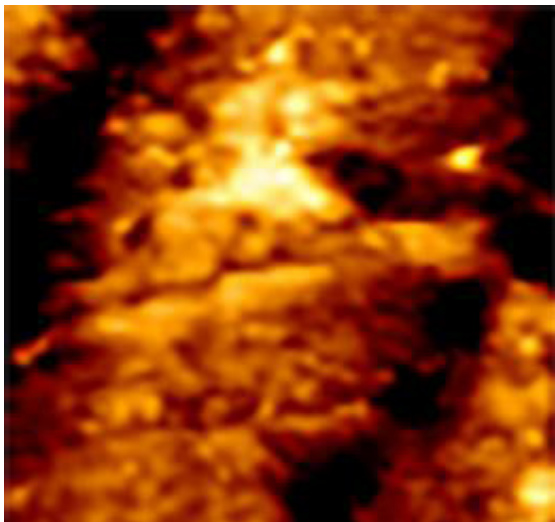
Student's *t*-test. A *p* value of less than 0.05 was considered statistically significant.

## Results

Table 1 shows the results of descriptive statistics on the wear depth in Acropars OP and 30 3A-GS060 groups. The measured wear depths of the study groups shows that 3A-GS060 group had a greater median wear depth and the range of measurements were also greater compared to the other group. The median wear depth for 3A-GS060 group was 6.00 $\mu$ m, which was higher than the Acropars OP group (2.00  $\mu$ m).



**Figure 2.** Nano Wizard II atomic force microscope



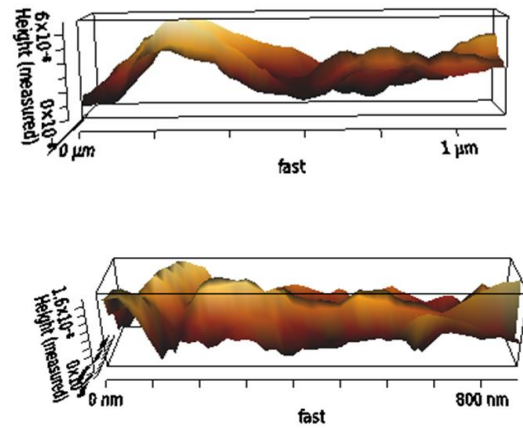
**Figure 3-A:** 2D topographic image of 3A-GS060 specimen

The mean wear depth was also higher in 3A-GS060 group (6.10  $\mu\text{m}$ ) compared to Acropars OP group (2.15 $\mu\text{m}$ ). The Student's *t*-test showed a significant difference between mean wear depths of two groups of the study ( $p < 0.001$ ). These results showed that 3A-GS060 group is less wear resistant than Acropars OP group.

**Discussion**

Retention is one of the main challenges the clinicians are faced in orthodontics, and choosing the proper methods and materials can be crucial in this regard [13,15,16]. There are various factors affecting the patients' cooperation and satisfaction in using orthodontic removable retainers. Some of these factors are aesthetics, cost, and comfort [4]. One of the factors that affects the prolonged use and cost-effectiveness of these retainers is their durability, and wear resistance of the appliance is one of the factors affecting its durability. The main focus of this study was to compare the wear resistance of two materials commonly used to make orthodontic retainers.

There are some studies comparing the patients' satisfaction, cost-effectiveness, and survival time of more traditional Hawley retainers and VFR materials,



**Figure 3-B:** 3D topographic images of points selected in specimen trough ( upper: 3A-GS060, lower: Acropars OP)

but according to a systematic review done by Mai *et al.* [10] the choice between them is still a matter of controversy; also, in terms of occlusal contacts, there is insufficient evidence to support the use of VFRs rather than Hawley retainers. Further studies are recommended to come to better conclusion in this regard. In our study, polymethyl methacrylate material was more wear resistant than polyethylene material, so it may be more wear resistant in clinical conditions, and higher wear resistance may improve the retainers' survival time and also cost-effectiveness. It was reported by Campbel *et al.* [9] that in a large number (38%) of patients, VFRs need to be replaced because they are worn too much. The high amount of wear in VFRs reported in their study reduces the retainers' service time and causes additional costs to patients. Lindauer *et al.* [8] also reported that VFRs break more than Hawley retainers. In contrast to them, Hichens *et al.* [4] compared the cost-effectiveness of Hawley retainers and VFRs, indicating that VFRs are more cost-effective in all aspects, such as patient satisfaction, comfort and fewer breakages. Sun *et al.* [17] and Capote [18] have both compared the clinical survival of these two retainers and reported that there was no significant difference between the percentage of breakage in the two types of retainers. One explanation for the differences between our results

**Table 1:** Descriptive statistics on the wear depth in Acropars OP and 3A-GS060 groups in  $\mu\text{m}$

Group	Median	Mean (SD)	IQR	95% C.I		p value
				Lower	Upper	
Acropars	2.00	2.15 (0.46)	0.70	1.815	2.484	<0.001
3A-GS060	6.00	6.10 (1.44)	2.50	5.063	7.136	

n = 30 per group. IQR indicates interquartile range; SD, standard deviation; CI, confidence interval for mean.

and others can be the complex nature of clinical wear; this is the net result of a number of fundamental processes, such as abrasion, adhesive effects of the contacting surfaces, fatigue, and corrosive effects, which act in various combinations depending on the physical properties of the contacting surfaces and materials [19]. Therefore, the lack of some clinical factors can affect the results of any laboratory study, similar to ours.

In this study, we used a 460 g weight on the antagonist balls and an experimental run of 1000 cycles, which was just similar to that of the Raja *et al.* [7], but the mean values for polyethylene materials in their study was about 11.4  $\mu\text{m}$ , which is about two times the mean measurements of the present study (6  $\mu\text{m}$ ). The reason for this difference can be the difference between the wear machines cycles used in the two studies. In our current study, in each cycle the antagonist was wearing the circumference of a circle once, but in their study it was wearing a 16mm line twice as much, because in one cycle their base plate was moving 16mm to the right on a straight line and then 16mm to left on the same line to its start position [7].

### Conclusions

- Acropars polymethyl methacrylate material was more wear resistant than 3A-GS060 polyethylene material, so in clinical conditions, Hawley appliances made by Acropars OP may have more durability than VFRs made by 3A-GS060.
- An appropriately designed, randomized, controlled clinical trial may be helpful to determine whether these findings are replicated in vivo.

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