

Shear force bond analysis between acrylic resin bases and retention framework (open- and mesh-type)

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Abstract. Occlusions between teeth and the activity of the muscles around an artificial tooth during mastication create a force on dentures. This force causes friction between acrylic resin bases and retention frameworks that can lead to the complete loss of the acrylic resin base from the framework. The purpose of this study was to analyze the design of retention frameworks and determine which ones have a better resistance to shear forces in order to prevent the loss of heat cured acrylic resin base (HCARB). Six samples each of open-and mesh-type retention frameworks, both types made of Co-Cr material, and HCARB, were shear tested by means of a universal testing machine. The average shear force required to release the HCARB for mesh-type retention frameworks was 28.84 kgf, and the average for the open-type was 26.52 kgf. There was no significant difference between the shear forces required to remove HCARB from open- and mesh-type retention frameworks.

1. Introduction

Loss of teeth can interfere with the functions of mastication, contribute to temporomandibular joint disorders, and can also result in speech function disorders as well as psychological and aesthetic issues. In order to rehabilitate a missing tooth, a denture needs to be made to restore tooth function. Dentures can be either fixed or removable [1]. Based on the material, there are two types of removable partial dentures: acrylic resin framework and metal framework. Metal framework dentures have several advantages compared to acrylic resin framework dentures. They are more convenient to use, more durable, more biocompatible, can break stress and have better stability. According to research by Janaina *et al.*, metal framework denture component damage most often occurs after five years of use by bending or shifting of the acrylic resin base of the retention framework [2-4]. Metal framework dentures comprise a major connector, minor connector, clasps, retention framework, and acrylic resin base. HCARB have been used in metal framework dentures as the place of attachment to the denture [5].

There are few studies that describe the best design of retention frameworks. According to Al Ali, failures that occur between the retention framework and the acrylic resin base can vary depending on the design of the retention framework used and the type of acrylic resin used [6]. There are several opinions among researchers. Boucher and Renner state that there are three types of commonly used retention: open-design, mesh-design and beads [7]. Al Ali reported that the heat cured acrylic resin material on the retention of the open-type shows greater strength, significantly to a shear force, than other types of mesh [6]. Brown *et al.* state that the mesh-type retention framework is preferable because it is more susceptible to deformation and metal failure [8]. According to Lee *et al.*, the various



forces required to release the acrylic resin for retention framework types, without primer, were greatest for beads followed by mesh, open, and smooth [9]. This is consistent with research by Fahad *et al.* who studied bonding acrylic resin with various types of retention frameworks [10]. Brudvik reported that retention beads are superior because they need less inter-arch space [11]. This is in contrast to Rodney *et al.*, who stated that this type of bead provides a relatively weaker bond with acrylic resin and its use is limited to a short span [5].

Good design of retention frameworks requires them to have mechanical retention that prevents the release of the HCARB. Both open- and mesh-types can be used for a long span, have similar indications, and are both widely used in the market. There are various forms of retention wax patterns, both open- and mesh-type, supplied by various manufacturers. This could have an effect on the magnitude of the resistance to shear force. Occlusion between the teeth and the activity of the muscles around the denture during mastication will cause forces including: occlusal, vertical, lateral, anteroposterior, and force displacement. Lateral forces arise when the lower jaw moves from its position to eccentric contacts positions in centric occlusion or vice versa [4]. The force causes friction between the acrylic resin base and the retention framework that can lead to complete loss of the acrylic resin base from the retention framework. Due to the lack of scientific information about the different types of retention framework design, this study analyzed the force required to remove a HCARB from open- and mesh-type metal retention frameworks.

2. Materials and Methods

The study was conducted using the universal testing machine at the dental materials laboratory at the Faculty of Dentistry, Universitas Indonesia. The specimen-type groups were heat cured acrylic resins with mesh-type and open-type retention frameworks. The Co-Cr composition used in this study is described in Table 1. The minimum number of samples in each group was five with a minimum total number of 10 specimens.

Table 1. Co-Cr alloy composition used in this research

Alloy	Composition (%)					Modulus of elasticity GPa	Tensile strength MPa	Brand
Co-Cr	Co	Cr	Mo	Silica	Additional	220	850	Co-Cr <i>Modellgusslegierung Degussa dental</i>
	64	28.5	5.0	1.0	N,Mn,C,W			

Sample frameworks were made with ready-made wax patterns. The open retention pattern shape had up to four holes per piece. The mesh retention pattern shape had 16 holes per piece. Group 1 comprised open-type Co-Cr models. Group 2 comprised mesh-type Co-Cr models. The specimens were made with red wax formed into a squares (length 8 mm; width 5 mm; thickness 6 mm) which were attached to the open-type Co-Cr specimen. Holes in the Co-Cr retention were filled with red wax up to 2 mm from the retention hole, then planted in a cast type two in the cuvette. Additionally, six red wax squares (length 8 mm; width 5 mm; thickness 6 mm) were attached to the mesh-type Co-Cr specimen. Holes in Co-Cr retention were filled by red wax up to 2 mm from the retention hole, then planted in a cast of type two cuvette. A boiling process was carried out by soaking them in boiling water for 5 minutes to remove the wax. Could Mold Seal (CMS) was applied to the surface of the cast type two. The heat cured acrylic resin was made by mixing the appropriate liquids and powders, stirred, and then inserted into the mold. The cuvette was closed and boiled in water for approximately 20 minutes, the cuvette cooled and opened to remove the specimens that had been fused between the Co-Cr and heat cured acrylic resin.

Shear tests, to release the HCARB from the open-type retention framework, were conducted on six open-type specimens. A universal testing machine was used with a load position above the surface of the contact between HCARB and parallel to the Co-Cr. Tests conducted on the universal testing

machine used a maximum load of 100 kgf and a speed of 1 mm/min; the amount of force to release the HCARB was noted. The data obtained were analyzed using SPSS version 20.0 and interpreted further. A univariate analysis phase was used to determine the frequency distribution of each variable to find the mean, standard deviation, maximum and minimum, and bivariate analysis.

3. Results and Discussion

3.1 Results

The shear force required to release the HCARB of the two types of retention frameworks (open- and mesh-types) can be seen in Table 2. The data distribution showed that the average release shear force was larger for the mesh-type retention framework (28.84 kgf). The average release shear force for the open-type retention framework was 26.52 kgf. The normal data distribution was tested using the Shapiro-Wilk test. The Shapiro-Wilk test showed that the force required to release the mesh-type retention was 0.672 and for the open-type retention it was 0.674. In this study, the data was analyzed using a bivariate analysis test form of an independent sample t-test (unpaired t-test) to compare the average value of the magnitude of force to release the HCARB from two types of retention frameworks. From Table 3, it can be concluded that there was no significant difference between the forces required to release the HCARB from the retention frameworks of either open- or mesh-types ($p>0.05$).

Table 2. Shear force required to release heat cured acrylic resin from two types of retention frameworks: open- and mesh-type

Retention type	Mean	SD	Maximum	Minimum
Mesh-type	28.84 kgf	3.84	34.30 kgf	22.45 kgf
Open-type	26.52 kgf	3.88	32.75 kgf	21.50 kgf

Table 3. Differences in the shear force required to release the HCARB of open- and mesh-type retention frameworks

Variable	Mean	CI 95%		p-value
		Lower	Upper	
Mesh-type	3.899	-2.661	7.295	$p>0.05$
Open-type	3.849	-2.317	7.295	

3.2 Discussion

This study was laboratory-based experimental research conducted to analyze and compare the magnitudes of the shear force required to remove a HCARB from an open- and mesh-type retention framework. According to research conducted by Al Ali (2009), the strength of the shear forces between the various types of acrylic resins and various types of retention frameworks on nickel chromium vary, depending on the type of material and the acrylic resin retention framework used [6]. In this study, open- and mesh-type retention frameworks were selected because of their similar indications and use in long spans [5]. The choice of mesh-type retention frameworks, in this study, was also based on research conducted by Lee *et al.* (2010) which stated that the shear force required to remove the acrylic resin heat cured base of mesh-type retention frameworks was greater than that required for open- type retention frameworks [9]. Research conducted by Fahad *et al.* (2012), on the bonding strength of a poly(methyl methacrylate) base denture on titanium and Co-Cr, with different designs, showed that mesh-type retention strength, against a shear force, is greater than the open-type [10].

The use of open-type retention frameworks, in this study, is based on a study by Boucher and Renner – the three most commonly used retention design types are open, mesh, and beads. Boucher

and Renner support the open-type but claim it has a high susceptibility to permanent deformation [7]. Research conducted by Al Ali (2009), on assorted acrylic resin bases with various types of nickel chromium retention frameworks, including heat cured acrylic resins, showed the strength against shear force is significantly higher for open-type frameworks compared to mesh-type retention frameworks [6]. After shear testing, the specimens were examined using a stereomicroscope, at 10 x magnification, to observe any heat cured acrylic resin remaining on the retention framework and to see if the fracture occurred along the mechanical bond between the framework and the HCARB. In the stereomicroscope photos (Figure 1), it appears that the mesh-type retention portion remaining on the HCARB is partially in the retention holes. The open-type largely left no heat cured acrylic resin in the retention holes or the entire specimen and the fracture occurred directly between the retention bond framework and the HCARB.

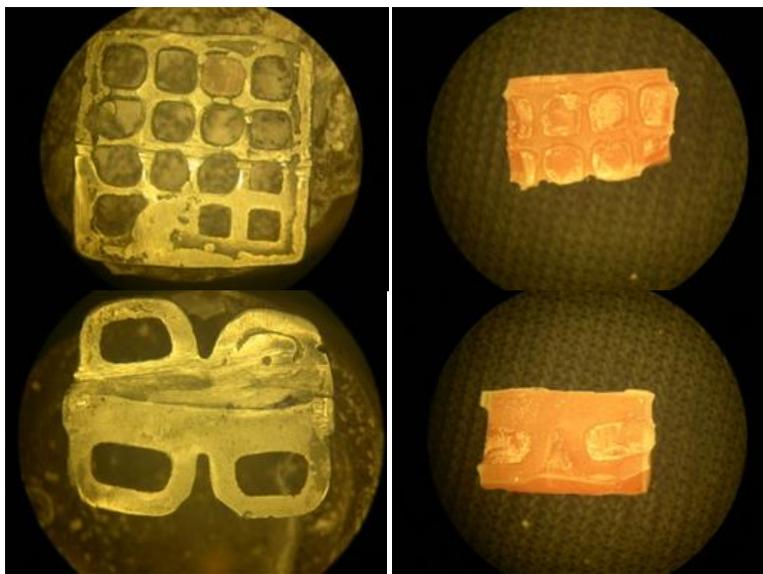


Figure 1. Specimen after tests, photos taken with stereomicroscope

Statistical analysis showed no significant difference between the two results. The shear force required to detach the acrylic resin heat cured base for the mesh-type retention framework is greater than the shear force required to detach the acrylic resin heat cured base of the open-type.

The results of this study differ from other studies. This may have been caused by differences in the surface area of the wax pattern used in each study and the form of the wax pattern used. This study used a Dentarum brand pattern wax with a box shape on the mesh-type and a loop shape on the open-type, whereas in the study done by Lee *et al.* (2010), they used a round shape for the mesh-type and a square shape for the open-type. Research conducted by Al Ali (2009) used the round shape for the mesh-type and square shape for the open-type manufacture by BEGO. It is also similar with the study by Al Ali (2009) which states that the strength of the shear force depends on the type of acrylic resin and retention type framework used [6]. A limitation of this study was the length of the specimen tested. The study would have provided better results if the specimen used was longer so that it would conform to the indication of the open- and mesh-types used in cases of long span which could not be done in this study because of the limitations of the test equipment used. Further research is needed on the force that can release the HCARB from the retention by a primary framework and the various denture base materials of different retention frameworks.

4. Conclusion

It can be concluded, from this study, that the shear force required to release the HCARB of the mesh-type retention framework is greater than that required to release the HCARB of an open-type retention framework. Open- and mesh-type retention frameworks can both be good choices as a denture base.

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