The Effect of Toothbrushing Duration on Nickel Chromium Alloy Wear

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Abstract

Nickel-chromium alloy is a preferred material for fixed partial denture due to its low cost as well as good physical and mechanical properties. Tooth brushing using toothpaste produces abrasion on restoration, especially in a long period. This study aimed to observe the effect of toothbrushing duration on the wear of nickel-chromium alloy. Twenty four specimens of nickel-chromium alloy (Metal 4all, Ivoclar, USA) in 30X15X1mm3 dimension were treated using tooth brushing simulation machine (wear test machine, pin on plate unidirectional movement type) and toothpaste (modification of Balsam formula). The brushing durations were 30.9, 77.25, 123.6, and 154.5 hours as the simulation of 2, 5, 8, and 10 years tooth brushing. Surface roughness and weight difference as abrasion indicator were measured and analyzed using one-way ANOVA followed by LSD test. Tooth brushing duration of 2, 5, 8, and 10 years increased nickel-chromium alloy surface roughness (Ra) by 0.16, 0.39, 0.43, and 0.56μm with weight loss of 8%, 15%, 23%, and 32 %, respectively. These differences were statistically significant ($p < 0.05$). The result of LSD test showed a significant effect ($p < 0.05$) between groups of toothbrushing duration. The increase of surface roughness affects the increase of wear volume of nickel-chromium alloy indicated by R = 0.11 for brushing duration of 2, 5, 8, and 10 years. The conclusion of this study was 10 years tooth brushing promoted wear on nickel-chromium alloy, which was indicated by the increase in surface roughness and weight loss.

Keywords: Nickel chromium alloy, abrasion, wear volume, weight loss, surface roughness

1. Introduction

One of the preferred restorations to replace missing teeth is Fixed Partial Denture (FPD) from metal. The FPD is either made of all metal or laminated with porcelain if aesthetic appearance is the primary consideration[1]. The main consideration in choosing the material for FPD is its wear resistance because FPD is expected to last long in oral cavity[2,3]. Metal restoration shows disadvantage in terms of aesthetics when compared to porcelain and composite resin, but it offers advantages among other restoration material: high fracture resistance, good marginal strength, and high accuracy as a substitution for missing natural teeth[4]. Another advantage of metal restorations is less removal of tooth structure required compare to porcelain restorations[5]. Factors which affect the decisions in choosing metal alloy for fixed denture restorations include price, physical properties and biocompatibility properties[6]. Widely used metal alloy in dentistry is nickel-chromium, mainly due to its lower price than gold, its high hardness, and its good physical as well as mechanical properties[5].

Abrasives compound on toothpaste can create grooves and scratches on the surface of the material or defined as abrasion wear[7]. Clinical factors which potential to promote changes on material surface in the oral cavity are occlusal wear due to mastication and abrasion caused by tooth brushing[8].

Factors influencing abrasion of restoration caused by tooth brushing include number of brushing motion, type of bristle, brushing pressure, abrasive materials in the toothpaste and brushing duration[8,9.] Abrasion due to brushing with toothpaste produces roughness on restoration material surface. Surface roughness affects aesthetic and biological properties of the material[8].

The effect of brushing on surface material related to long-term longevity of restoration in oral cavity needs to be considered in deciding restorative materials[8,10]. Smooth restoration surface is necessary because food debris easily accumulated on rough surfaces which is difficult to be cleaned. Rough restoration surfaces cause the patients to feel less comfortable11 also induce more plaque accumulation that promotes gingival inflammation around the restoration[12,13.] Surface roughness increases when brushing duration is longer[14.]

Nickel-based metal is composed of a unit cell, called face-centered cubic, means that the atoms are arranged in every corner of the cube and at the center of each cube surface[15]. After being subjected to abrasion, the composition of nickel-based metal crystals shifts deeper, and the dense granules composing the metal turn into an irregular state then lead to the increase of the surface roughness16. Abrasion due to brushing using toothpaste is a kind of wear and tear that results in increasing roughness of restoration surface which affects aesthetic and biological properties of materials[8] as well as promotes the increasing release of metallic elements into the oral environment[10]. This study aimed to investigate the effect of toothbrushing

duration on the wear of nickel-chromium alloy.

2. Material and Method

Twenty four nickel-chromium alloy (Metal 4all, Ivoclar, USA) specimens in 30mm length, 1mm width, and 1mm thickness were divided into four brushing duration groups. Each group consisted of six specimens. Each specimen was made by casting process using Centrifugal Casting Machine (Manfredi Century, Magnum Digital, Germany). Finishing and polishing process according to laboratory procedures resulting in initial metal surface roughness <0.19 μm was applied to all specimen. Specimens were treated using brushing machine (wear test machine, unidirectional pin on plate movement type) (Fig.1) with medium hardness toothbrush (Formula, Indonesia). Specimens were planted in acrylic resin then submerged in a solution of distilled water with toothpaste (in 1:1 w/v ratio of toothpaste and distilled water). Toothpaste composition was prepared according to modification of Balsam et al. in 1972 (calcium carbonate, glyceryl, lauryl sulphate, CMC, saccharin, oil candy). The pre-prepared acrylic resins were positioned on a base which able to move back and forth with frequency of 2.33 Hz and stride length of 25 mm with a speed of 116.5 mm/sec 17. Brushing durations of 2, 5, 8, and 10 years were simulated by converting the frequency of brushing machine motion according to the research by Wataha et al.[10].

Description: 1. The load balancer (FA), 2. Main load (FB) 3. Load brushing (FC) 4. Armload (L1) 11,5cm, (L2) 12.5 cm, (L3) 50 cm, 5. Brush holder, 6. Box containing liquid toothpaste, 7. Toothbrush holder pin, 8. Resin plate, 9. Liquid containing toothpaste, 10. Toothbrushes.

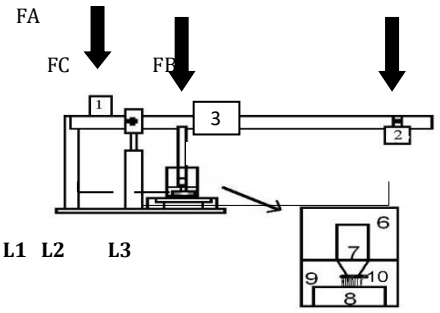

Figure 1. Scheme brushing machine [17].

A 2000g load was employed on the load balancer so that the tips of toothbrush bristle were in contact with the plate without generated pressure. This balance position was evaluated using a water pass. The main load of 50g weight was placed on the rod so that the tip of pin was in contact and the surface of bristles pressing the metal plate of nickel-chromium alloy with a pressure of 200g. Brushing was conducted for 30.9, 77.2, 123.6, and 154.5 hours which were equivalent to brushing period 2, 5, 8, and 10 years, respectively. The toothbrush was replaced every 3.9 hours as equivalent to brush replacement every 3 months. Initial weight (mg) before brushing and final weight (mg) after brushing of the specimens were measured using analytic balance (Mettler Toledo AG 285, Greifensee, Switzerland). The measurement was performed three times and the average weight (mg) of each specimen was considered as the result.

Initial surface roughness (µm) before brushing and final surface roughness (µm) after brushing were measured using surface roughness measuring instrument (Surfcorder tool SE 1700, Kosakalab, Tokyo, Japan). Each measurement was performed in two different locations on the mid-line of specimen and the average value of surface roughness (µm) of each subject was considered as the result. Data were analyzed using one-way ANOVA statistical test to determine the effect of brushing duration on nickel-chromium alloy wear, followed by Least Significant Difference (LSD) test to determine the difference between groups with different brushing duration.

3. Results

Figure 2 showed mean surface roughness of nickel-chromium alloy elevated as the increase of brushing duration. The highest mean of surface roughness (Ra= 0.56µm) was obtained after brushing for 154.5 hours. Measurement of each brushing period showed weight decrease compared to previous period (Fig. 3). Mean weight of nickel-chromium alloy decreased 32% after brushing for 154.5 hours. Figure 3 showed increased surface roughness (Ra) influenced increment of wear volume as indicated by R2 = 0.014 (R = 0.11).

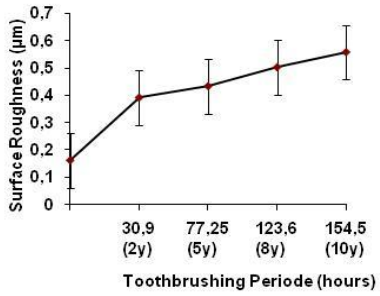

Figure2. Diagram of the relation line between toothbrushing period with the mean roughness of nickel-chromium alloy surface

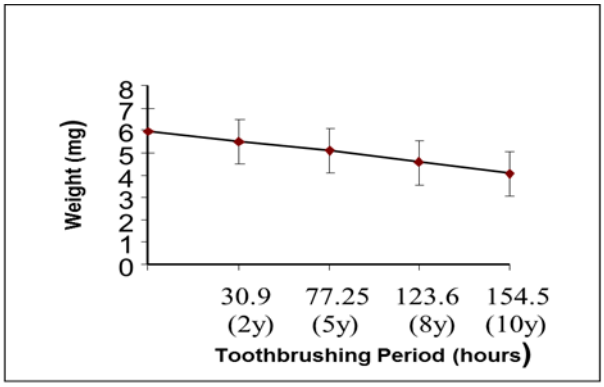

Figure 3. Diagram of the relation line between toothbrushing period with the mean weight of nickel-chromium alloy

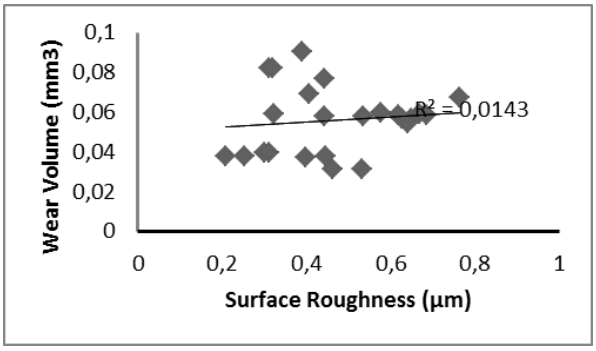

Figure 4. Diagram of relationship between surface roughness with the wear volume of nickel-chromium alloy

The result of one-way ANOVA test showed brushing duration affected surface roughness of nickel-chromium alloy ($p < 0.05$) and weight reduction of nickel-chromium alloy ($p < 0.05$). The LSD test results showed significant difference in surface roughness ($p < 0.05$) between groups after various brushing durations (Table 1). Besides, significant difference of weight reduction ($p<0.05$) between groups was found after diverse brushing durations (Table 2).

Table 1. LSD test between toothbrushing period with a surface roughness (μm) of nickel-chromium alloy surface

Brushing Duration	30,9 h (2 y)	77,25 h (5y)	123,6 h (8y)	154,5 h (10y)
0 h	0,14983*	0,29497*	0,44084*	0,56052*
30,9 h	*1)*	0,14514*	0,29100*	0,41069*
77,25 h	*2)*	*3)*	0,14587*	0,26555*
123,6 h	*4)*	*5)*	*6)*	0,11968*

Table 2. LSD Test between toothbrushing period with a weight reduction (mg) of nickel-chromium alloy surface.

Brushing	30,9 h	77,25 h	123,6 h	154,5 h
Duration	(2 y)	(5y)	(8y)	(10y)
Awal	0,47198*	0,89839*	1,40081*	1,91667*
30,9 jam	*1)*	0,42641*	0,92883*	1,44469*
77,25 jam	*2)*	*3)*	0,50242*	1,01828*
123,6 jam	*4)*	*5)*	*6)*	0,51586*

4. Discussion

This study showed increasing wear of nickel-chromium alloy, indicated by elevating mean of surface roughness and decreasing mean of weight, on the increasing of brushing duration. One-way ANOVA test showed brushing duration had a significant effect on the increase of wear on nickel-chromium alloy. The results were consistent with the hypothesis that brushing duration affects the increase of wear of nickel-chromium alloy.

Abrasion is one type of wear that occurs on a restoration[9]. Abrasion on a restoration is defined as the substance loss of object surface by direct friction between the surfaces of an object with another object or friction force between surfaces with the presence of abrasive materials as the medium18. The presence of abrasive material in the friction between the components creates three-body abrasion[19]. It indicates that when brushing with toothpaste, wear processes occur due to friction between the surface of the brush, toothpaste abrasive materials, and nickel-chromium alloy surface.

Abrasives compound on the toothpaste used in this study was calcium carbonate with particle size of 3μm-10μm[20]. The size of abrasive particles influences the occurrence of wear[19]. Hutchings[19] stated the size of abrasive particles that can cause wear was ranged between 5μm-500μm. The larger the size of abrasive particles means that the larger surface contact area created between abrasive material and the object thus more extensive and deeper scratches created so the surface wear will occur faster.

LSD test showed significant differences of nickel-chromium alloy wear between group with different brushing duration. This was consistent with Hutchings[19] who stated that wear volume is proportional to the distance passed by the surface of an object in friction with another object. In this study, friction distance passed was analogous to brushing duration, thus longer brushing duration increased wear volume of materials.

Scratches on surface of material were caused by pressure applied to an object or by sharp tipped abrasive materials5. Owal et al. [21] also suggest that the type and amount of pressure exerted mechanically affects the wear process. Brushing with toothpaste conducted in this study produced constant friction between brush and metal as well as between abrasives in toothpaste with nickel-chromium alloy surface. The pressure promotes the atoms in the crystal lattice to displace elastically in a small amount so if the pressure is released, the atoms will return to their original position. If the proportional limit is exceeded, elastic and plastic deformation occurs and load removal is not followed by re-arrangement of atomic structure to its original dimension. Only the elastic strain will return. Increasing pressure produces a great amount of shift between atoms; the atoms are separated each other so the plastic deformation occurs5. The friction force between brushes, abrasive material, and metal surface change the position of grains in the alloy which initially binds to each other by the grain boundaries so that the grains in the alloy were released from their bound and resulted in rough surface[22].

The volume of wear increases along with the increase of surface roughness. Metal elements released into the oral cavity affect biocompatibility properties of the metal such as indicated by the changes in the local responses of the gingival tissue in contact with metal alloys. This is consistent with the study of Wataha et al. [10] which showed that brushing the metal alloy elevated alloy elements release which in turn increased cell toxicity in vitro. Increased surface roughness reduces patients comfort on wearing fixed partial dentures. The release of metal substance because of wear process related to weight loss of metal. Reduction of metal weight leads to metal thinning so that the resistance of metal against chewing pressure decreases [23].

5. Conclusion

From the results of this study on the effect of toothbrushing duration on nickel-chromium alloy, we concluded 10 years brushing duration influenced the increase

of surface roughness ($p<0.05$) and weight reduction of nickel-chromium alloy ($p<0.05$). The increase of surface roughness affects the increase of wear volume of the nickel-chromium alloy indicated by R = 0.11 for brushing duration of 2, 5, 8, and 10 years.

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