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Influence of reinforcing materials on strain of maxillary complete denture

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Abstract

Objective. A maxillary complete denture has been a common prosthetic treatment for people with edentulous maxillas. The fracture and deformation of dentures are recurrent and common problems for denture-wearers. Consequently, reinforcement materials are embedded in the denture base to prevent fracture and deformation. The purpose of this study was to examine the influence of reinforcing materials on the strain within the acrylic base of a maxillary complete denture. ***Materials and methods.*** Three reinforcements (cast cobalt-chromium bar; glass fibers; and cobalt-chromium wire) were embedded in the bases and a strain-gauge was attached at three positions (labial, middle and posterior) at the mid-line of the polished surface of each denture. A vertical occlusal load of 49 N was applied to the left and right side in the region of the 1st premolar and the 1st molar. Comparisons of the strain were made via ANOVA. ***Results.*** The strain of the denture base with a cast cobalt-chromium reinforcement was significantly ($p < 0.05$) smaller than that with the other reinforcements. ***Conclusions.*** This result suggested that a cast cobalt-chromium reinforcement helps to reduce the risk of fracture and deformation of a maxillary complete denture.

Key Words: *cobalt-chromium, glass fiber, maxillary complete denture, reinforcement, strain*

Introduction

The fracture and deformation of maxillary complete dentures have been significant prosthodontic problems in clinical practice. Darbar et al. [1] reported that 29% of the fractures occurred at the mid-line of upper complete dentures. To prevent fracture, various materials have been embedded in the denture base. For example, metal wire [2–4], cast alloys [5–7] and glass fibers have been used. The reinforcing effect of metal wire has been compared to glass fibers [8-10]. It was reported that there was no difference on the reinforcing effect between metal wire and glass fibers. Apparently, cast metal is more effective than a metal wire [7] and glass fibers are more or as effective as metal wire [11]; however, cast metal reinforcement has not been compared to glass fibers.

The purpose of this study was to examine the influence of three reinforcing materials (cast cobalt-chromium bar; glass fibers; and cobalt-chromium wire) on the strain of a maxillary complete denture and to reveal the difference of the reinforcing effect among cast metal, glass fibers and a metal wire.

Materials and methods

A plaster cast of an edentulous residual ridge (G2-402U, Nissin, Kyoto, Japan) was fabricated and covered with silicone rubber (Fit Checker, GC, Tokyo, Japan) to simulate a 2 mm-thick mucosal lining. An acrylic resin base (Parapress Vario, Heraeus, Hanau, Germany) was fabricated on the model to simulate a base plate with an occlusal rim. The thickness of the palate of the model is 1.5 mm and the height of the rim is 8.5 mm in the posterior region and 11.5 mm in the anterior region. A standard pouring method was used to process the resin and one of the three reinforcements—cobalt-chromium wire (Wire: 0.8 mm diameter; Sun-cobalt clasp-wire, Dentsply-Sankin, Tokyo, Japan); cast metal (Co-Cr: 4 mm wide × 0.5 mm thick, Cobaltan, Shofu, Kyoto, Japan); and glass fiber (GF: 4 mm wide × 0.5 mm thick, FiberKor, Pentron, CT)—was embedded from

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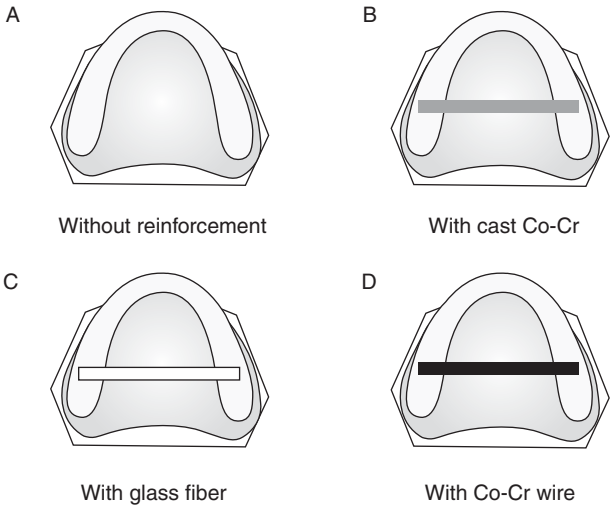

Figure 1. Schematic illustrations of dentures with reinforcements. (A) Without reinforcement (Control); (B) with cast Co-Cr (4 mm wide × 0.5 mm thick) reinforcement (Co-Cr); (C) with glass fiber (4 mm wide × 0.5 mm thick) reinforcement (GF); and (D) with Co-Cr wire (diameter, 0.8 mm) reinforcement (Wire).

1st molar to 1st molar before the resin polymerized (Figure 1). The strength of each reinforcement design was tested against a control base without reinforcement. The Co-Cr and wire reinforcements were sandblasted with 50 μm alumina, cleaned in an ultrasonic cleaner in distillated water for 15 min, wiped with 78% ethanol and coated with metal primer (Metal Primer II, GC, Tokyo, Japan).

A strain gauge (KFG-02-120-C1-11L1M3R, Kyowa Electronic Instruments, Tokyo, Japan) was attached at the labial, the middle and the posterior position at the mid-line of the polished surface of each denture (Figure 2) and connected to the sensor interfaces (PCD-300A, Kyowa Electronic Instruments, Tokyo, Japan) and controlled by a personal computer (Dynabook SSN10, Toshiba, Tokyo, Japan). A vertical occlusal load of 49 N was applied to the left and right side in the region of the 1st premolar and 1st molar through a brass bar (5 mm wide × 5 mm thick × 100 mm length)

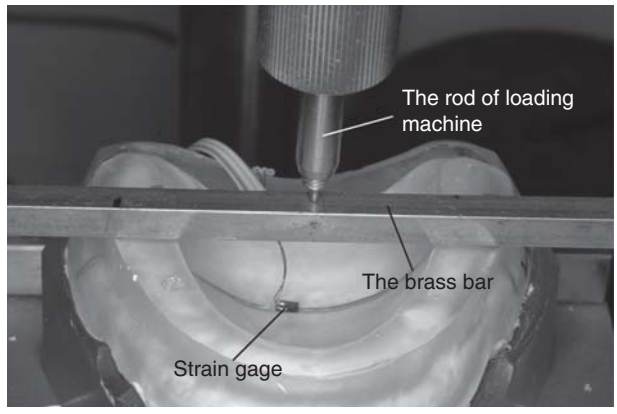

Figure 3. Photograph of the loading apparatus. A vertical occlusal load of 49 N was applied to the left and right side in the region of the 1st premolar and the 1st molar. This photograph shows the case of loading at the 1st molar. (A) The rod of the loading machine; (B) the brass bar; and (C) the strain gauge.

attached to the loading apparatus (Figure 3). The strain of each experimental denture was recorded for 10 s, with an intervening interval of 50 ms. All measurements were repeated five times for each denture and each load.

Comparisons were made of the measurements of strain via ANOVA with a post-hoc comparison using the Bonferroni method. All statistical analyses were performed with SPSS Ver.11 (SPSS, Chicago, IL).

Results

In the 1st-premolar region, the strain of the Co-Cr was less significant ($p < 0.05$) than other types at the labial position, whereas Co-Cr and GF were strained less significantly ($p < 0.05$) than the Control or Wire at the both the middle and the posterior positions (Figure 4).

In the 1st-molar region, the strain was less significant ($p < 0.05$) with reinforcement than for the Control at the middle position and the strain of Co-Cr was the least, followed by GF, Wire and Control (Figure 4).

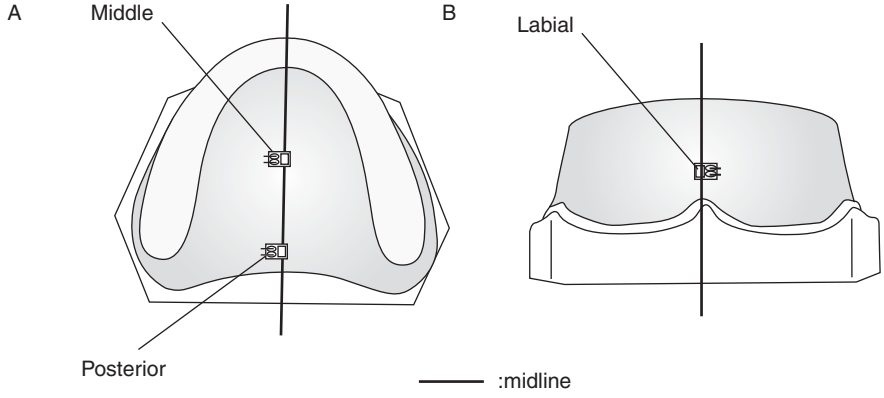

Figure 2. Schematic illustrations of position of strain gauges. (A) Occlusal view and (B) labial view. Strain gauge attached at the labial, middle and posterior position at the mid-line of the polished surface of each complete denture.

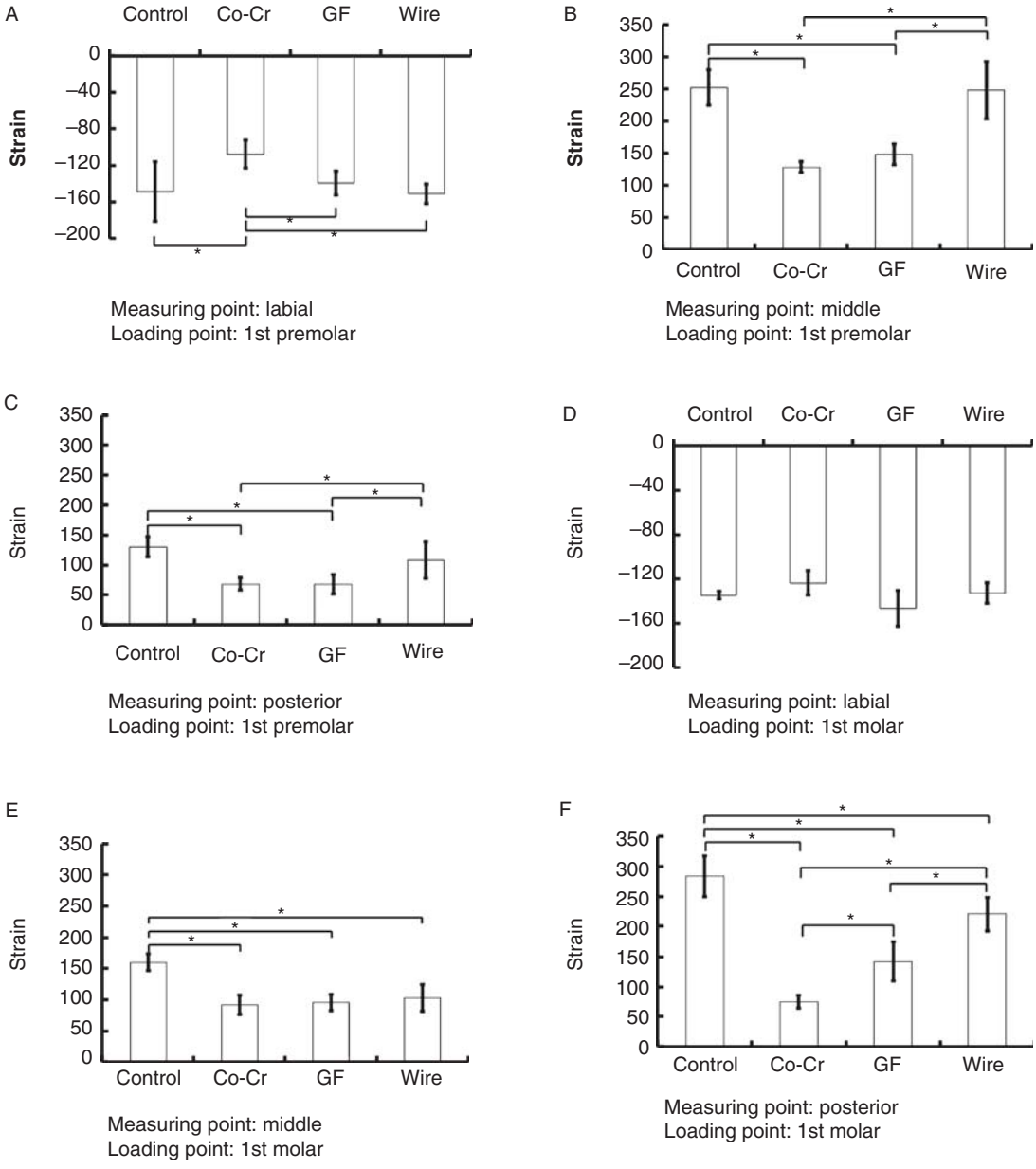

Figure 4. Graphs of strain in denture base. Significant differences of mean values are marked by an asterisk (*$p < 0.05$). (A) Measurement position: labial, loading position: the 1st premolar; (B) measurement position: middle, loading position: the 1st premolar; (C) measurement position: posterior, loading position: the 1st premolar; (D) measurement position: labial, loading position: the 1st molar; (E) measurement position: middle, loading position: the 1st molar; and (F) measurement position: posterior, loading position: the 1st molar. Control: Without reinforcement. Co-Cr: With cast Co-Cr reinforcement. GF: With glass fiber reinforcement. Wire: With Co-Cr wire reinforcement.

Discussion

Clinical reports suggest that the most common fracture site of maxillary complete dentures is in the midline [1,12,13]. To prevent fracture of the denture base, various materials have been embedded to reinforce the dentures, such as a metal wire and plate, glass fibers and carbon fibers [14]. Glass fibers have been used as a reinforcement of composite resin for fixed partial dentures [15] and for removable partial dentures because they are easy to use [16,17]. Various types of glass fibers, such as woven [18–21], short-rod [22], bundle [23] and continuous [8,9] were investigated and it was reported that all types were effective to reinforce. There were many studies about the reinforcing effect comparing without reinforcement and with reinforcing materials, but there were few studies about the reinforcing effect comparing among reinforcing materials.

The standardized acrylic resin bars containing the various reinforcing materials [24] are often used to examine the reinforcing effect. The reason is that it could be readily fabricated and provided data on the relative increase in stiffness of the different

configurations. However, using the models to simulate dentures is more clinical than using the standardized acrylic resin bars.

Ruffino [25] reported that reinforcement should be placed perpendicular to the anticipated line of stress and fracture. Prombonas et al. [26] reported that the largest tensile strain was recorded in the palatal region of maxillary complete denture and the direction of the tensile strain was perpendicular to the mid-line of the denture. Howell et al. [27] reported that the maximum bite force when chewing foods occurred at the first molar. The reinforcements of this study were designed in consideration of the results of these reports.

To simplify the study and avoid variables that could introduce error, we conducted all experiments with a vertical loading. We selected 49 N as the load, which was measured as maximum bite force at the first molar of complete denture wearers in a previous study [7].

Hirajima et al. [11] examined the reinforcing effect of a cobalt-chromium wire and a glass fiber in a similar situation to this study and reported that both a cobalt-chromium wire and a glass fiber reinforcement significantly reduced the deformation of denture. However, both the glass fiber and metal wire offered similar resistance to the strain in a denture base. In our study, the strain of a glass fiber reinforcement was significantly smaller than that of a metal wire, which differed from the results found by Hirajima et al. [11], probably because the GF reinforcement used by Hirajima et al. was narrower and the metal wire thicker. The reinforcing effect became greater as the reinforcing materials thicken and widen, while the strain with glass fiber reinforcement was significantly smaller than that of a metal wire reinforcement. Gonda et al. [7] reported that a cast cobalt-chromium reinforcement decreased the strain of the denture base more than a cobalt-chromium wire reinforcement, which was supported by our results. It seems therefore that a cast cobalt-chromium reinforcement is more effective than a cobalt-chromium wire reinforcement.

We used a simple experimental denture base and loaded it vertically with a simulated occlusal force. However, there is lateral force acting on a denture when chewing or biting, therefore vertical and lateral force should be applied when testing resistance to strain in future studies.

The results of this study suggested that both a glass fiber and a wire reinforcement could reduce the strain at the only region directly on the reinforcement, but the cast cobalt-chromium reinforcement reduced the strain over a wider area. Maeda et al. [28] reported that to prevent fracture and deformation of dentures, the rigidity of the reinforcement of the denture is necessary. Although glass fibers and a cobalt-chromium wire are easy to shape they are less rigid than the cast Co-Cr. Some reported that glass fiber cannot, by its fibrous nature – stiffen the denture base in large scale and, therefore, increased strain values cannot be observed. However, use of glass fiber has proved to be effective reinforcement by its capability to act as a crack stopper for minor cracks which could continue to fracture without fibers [29,30]. This study suggests that a cast cobalt-chromium reinforcement decreases the strain the most and may be more effective than glass fibers and wire reinforcement when reinforcing the maxillary complete denture.

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