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Original article

Clasp fabrication using one-process molding by repeated laser sintering and high-speed milling

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ABSTRACT

Purpose: A single machine platform that integrates repeated laser sintering and high-speed milling for one-process molding has been developed.

Methods: The Akers clasp was designed using the CAD system (DWOS Partial Frameworks, Dental Wings) and fabricated using repeated laser sintering and a high-speed milling machine (LUMEX Advance-25, Matsuura) with 50-μm Co–Cr particles (CAM clasp). As controls, cast clasps of the same forms were also prepared using conventional casting methods with a Co–Cr alloy and CP titanium Grade 3. After the surface roughness was measured, the gap distance between the clasps and the tooth die was assessed using the silicone film method. The initial retentive force and changes in retention up to 10,000 cycles were also measured. The data were analyzed using two-way ANOVA and Tukey's multiple comparison test ($\alpha = 0.05$).

Results: CAM clasps exhibited significantly smoother surfaces than those of cast Co–Cr and CP Ti clasps ($p < 0.05$). However, the gap distances of the CAM clasps were significantly greater than those of the cast clasps ($p < 0.05$). The retentive forces of both CAM and cast Co–Cr clasps were significantly higher than those of CP Ti clasps. ($p < 0.05$). The retention of CAM clasps demonstrated a constant or slight decrease from 1000 up to 10,000 cycles.

Conclusions: The CAM clasp made by repeated laser sintering and high-speed milling can be used effectively as an RPD component.

1. Introduction

Dental computer-aided designs and computer-aided machining (CAD/CAM) technology has rapidly improved from the beginning of the 21st century with the remarkable development of digital technology [1–4]. Using CAD/CAM, prostheses with higher mechanical properties and better fitness accuracy can be fabricated as compared with the conventional casting method [5–9]. The CAM system has mostly used metal and zirconia blocks in the milling process for fabricating prosthetic frameworks. However, the following disadvantages of the milling process have been identified: (1) it is not easy to manufacture complicated shapes and/or undercut areas, (2)

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large quantities of cutting chips are discharged, (3) milling accuracy deteriorates when cutting tools are worn, and (4) long processing times are required. Thus, milling would not be a suitable method for fabricating a removable partial denture (RPD) framework with a clasp because of its long, narrow shape with an undercut. For the development of dental CAD/CAM manufacturing, especially RPD framework fabrication, a new machining process should be introduced.

Compared to the milling process, repeated laser sintering has many advantages: (1) no cutting chips are produced; (2) shapes with free curves, undercuts, and hollow structures can be fabricated; (3) accuracy is not diminished by worn cutting tools; (4) many frameworks can be prepared simultaneously; (5) the process is totally automatic; and (6) the cost is relatively low [10,11]. A Co–Cr alloy prepared using laser sintering showed higher tensile strengths, with 0.2% proof stresses, than did those prepared using the conventional casting method [12–14]. Because rather fine alloy particles (50 μm) are now used in the laser sintering method, the metallographic structure is microscopic in size, and the mechanical properties would become too high [15–17]. However, the surface of the sintered framework is considerably rougher than that with milling manufacturing. In addition, the hardness and mechanical properties might decline due to the anisotropy of laser sintering [18–20]. Annealing at approximately 1000 °C would viably reduce the mechanical anisotropy to a low level in a Co–Cr–Mo alloy manufactured by laser sintering [21,22].

To create a smooth surface on a framework manufactured using laser sintering, a single machine platform that integrates repeated laser sintering and high-speed milling (15,000/min) for one-process molding has been developed. The manufacturing procedures are as follows: (1) squeezing—laminating 0.05-mm thick metal powder as a material on a molding and processing table; (2) laser sintering—the laser beam is irradiated to sinter the metal powder into the shape of the product to be bonded to the processing table. After the metal powder is sintered, squeezes and supplies metal powder with a thickness of 0.05 mm to form the next layer and sinter all the laminated layers. Steps 1 and 2 are repeated 10 times. When the thickness reaches 0.5 mm, it moves to the milling stage. (3) Milling—the end mill performs precise high-speed milling of the mold's contours to a fine finish. The sintering and milling of the product are repeated to construct the layers from bottom to top. This machine can build up laminated layers by metal laser sintering and continuously mill them at a high speed, making possible both high precision and smooth surfaces without post processing. An RPD framework with a clasp may be made more precisely and economically using a hybrid metal 3D printer with a one-process solution of laser sintering and milling than by using laser sintering or milling manufacturing alone.

The purpose of this study was to evaluate the Akers clasp assembly prepared with Co–Cr alloy particles by one-process laser sintering and milling as compared to Co–Cr and commercial titanium (CP Ti) clasps cast conventionally. After nondestructive inspections, the surface roughness, fitness accuracy, initial retentive forces, and changes of retentive forces up to 10,000 insertion/removal cycles were measured to assess the suitability of the process for clinical use.

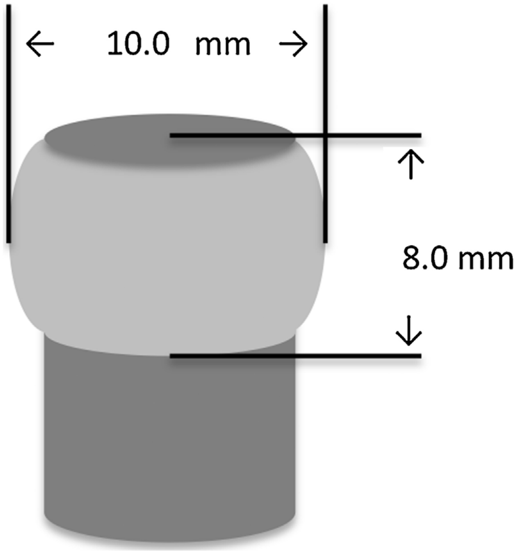

Fig. 1 – Illustration of the die simulating the first molar.

2. Materials and methods

2.1. *Fabrication of cast clasp specimens*

An 18-8 stainless steel die simulating the first molar (diameter: 10.0 mm, height: 8.0 mm, radius of curvature: 7.5 mm) was prepared as shown in Fig. 1. After impressions of the die were made with silicone impression material (Duplicone, Shofu, Kyoto, Japan), a working cast was fabricated with hardened plaster (New Fuji-Rock, GC Corp., Tokyo, Japan). Dental surveying was performed, and the Akers clasp outline was marked on the master cast. After an impression of the master cast was made with the same silicone impression material mentioned above, a duplicate cast was made with two phosphate-bonded Al_2O_3/LiAl SiO_6 investment materials (Heravest M, Heraeus Kulzer Osaka, Japan, for Co–Cr alloy and T-invest, GC Corp Tokyo, Japan, for CP Ti).

As shown in Fig. 2, Akers clasp assemblies were designed so that the retentive arms (12-mm lengths) were placed on 1/2 of the undercut area, and the tips were engaged at the 0.25-mm undercut 6.0 mm from both clasp tips. Occlusal onlay rests and clasp bodies 5.0 mm wide were added for all clasp arms. Patterns of the Akers clasp were fabricated with commercial ready-made wax patterns (RKG, Dentaurum, Ispringen, Germany) on the duplicate cast and invested in same phosphate-bonded investment materials mentioned above. They were cast with two dental alloys, Co–Cr alloy (Wisil, DENTSPLY-Sankin, Tokyo, Japan) and CP titanium Grade 3 (T-alloy H, GC Corp.), in accordance with the manufacturers' instructions. All castings were sandblasted with 50-μm Al_2O_3 particles under 0.5-MPa atmospheric pressure. CP titanium specimens were chemically treated with HNO_3/HF solution (Chemi-Polish, Shofu) for 2 min.

2.2. *Fabrication of CAD/CAM clasp specimens*

Similarly to cast clasp fabrication, a working cast was fabricated with hardened plaster (New Zo-Rock, Shimomura