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Influence of Different Undercut Depths of Clasp Fabricated by Selective Laser Melting on Retentive Force

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ABSTRACT

Introduction: The purpose of this study was to investigate the influence of undercut depths on abutment teeth regarding the retentive force of clasps fabricated through selective laser melting (SLM), and to compare them with conventional cast clasps. Methods: Akers clasps made of cobalt chromium alloy were fabricated using the SLM method (SLM), and the retentive forces were compared with clasps made with the conventional cast method (Cast). Three undercut amounts (0.25 mm, 0.15 mm, and 0 mm) were applied on the abutment tooth. The specimens were subjected to 10,000 repetitive insertion/removal cycles. Results: SLM-0.15 showed slightly lower initial retentive force than the Cast specimens, it remained within an acceptable range. During insertion/removal test, the SLM-0.15 specimen showed a significant difference between the initial retentive force and the retentive force after 5,000 cycles, indicating that SLM-0.15 was the least likely to change in retentive force within the parameters established in this study. The inner clasp surface on the SLM groups had higher surface roughness before testing compared to the Cast specimen. Conclusions: Akers clasps fabricated by SLM demonstrated optimal initial retentive forces with smaller undercuts than conventional Cast clasps, and the retentive forces changed less with repetitive insertion/removal.

INTRODUCTION

Removable partial dentures serve as a prosthetic option that can be applicable to all partially edentulous dentition from a single missing tooth to a single remaining tooth. Globally, approximately 158 million individuals experience partial or complete edentulism. In addition, more than 13% of the adult population use removable partial dentures in the United States and Europe.[1]

Numerous retainer options are available for removable partial dentures, including clasps and attachments. Among these, the circumferential clasp holds prevalence in clinical practice.[2] The effectiveness of clasp retention relies on the metal's resistance to micro-deformation. Successful clasp retention necessitates placement within an undercut area of the tooth, causing deformation upon vertical dislodging forces. This elastic deformation deformation along a properly chosen insertion path yields retention. Research highlights the relationship between the abutment tooth undercut, clasp arm configuration and material, and friction between clasp interior and abutment tooth in generating retentive forces via micro-deformation of the clasp arm.[3-5]

The design of the Akers clasp, known as a circumferential clasp, is standardized in the Ney surveyor manual published in 1963. This design was originally established under the presumption that the clasp will be made using gold-platinum alloy.[6] However, due to the recent rise in the cost of gold alloys, cobalt-chromium (Co-Cr) alloys have emerged as a clinical alternative, recognized for their high strength, elastic modulus, and exceptional corrosion resistance.[7] As for the manufacturing technology, the introduction of computer-aided design (CAD) and computer-aided manufacturing (CAD/CAM) technology has expanded the possibilities of cast production beyond the traditional casting method.[8] Moreover, the selective laser melting method (SLM) where metal powder is laminated with laser, has garnered significant attention. Clasps made using SLM have superior fabrication accuracy and physical properties such as 1.2 times for 0.2% yield strength, compared to clasps made by casting method;[9,10] however, clasps made through this method have a rough surface texture.[11] Studies have reported that the initial retentive force of clasps via SLM was higher than those produced by casting.[10,12-14] Furthermore, following repetitive insertion/removal tests, simulating denture placement and removal, the retention force declined less in SLM fabricated clasps in comparison to those from the casting method.[15,16] This suggests that SLM clasps could exhibit superior long-term stability.[17]

In clinical practice, excessive retentive force of the clasp has been reported due to improper design or errors during the fabrication process of removable partial dentures.[18] This situation may lead to the destruction of the periodontal tissues surrounding the abutment tooth.[19] Hence minimizing the retentive force of the clasp is an important requirement to reduce excessive loading and ensure the preservation of the abutment tooth.[20] This requirement is necessary regardless of whether the clasp is made using the Ney surveyor manual with gold-platinum alloys via the casting method or with cobalt-chromium alloy via SLM. Nevertheless, given the distinct physical and surface characteristics of SLM-fabricated clasps in comparison to conventional methods, a novel design should be proposed based on the appropriate retentive force. The purpose of this study was to investigate the influence of undercut depths on abutment teeth regarding the retentive force of clasp fabricated through selective laser melting (SLM), and to compare them with conventional cast clasps. The null hypothesis was that the amounts of undercut on abutment teeth would not affect the retention forces, both the initial and after repetitive insertion/removal, of clasps produced by SLM.

MATERIALS AND METHODS

PREPARATION OF METAL ABUTMENT TEETH

For the measurement of clasp retentive force, thirty-two metal abutment teeth were prepared. The abutment tooth was for the mandibular right second premolar tooth. The crown form of the abutment tooth was waxed-up, and the insertion/removal direction was aligned parallel to the clinical abutment axis. The wax pattern was designed with a guide plane on the distal surface, an axial plane parallel to the guide plane on the lingual surface, and a rest sheet on the distal marginal ridge. The prepared wax pattern was 3D scanned with a scanner (D2000, 3shape, Copenhagen, Denmark) to acquire STL data. For refining the metal abutment tooth form and designing the STL data, the CAD software (exocad version 3.0, exocad, Darmstadt, Germany) was used. The metal abutment tooth possessed dimensions of 8.7 mm in height and 6.9 mm in width. Throughout this process, projections were added on the occlusal surface to facilitate attachment to the repetitive insertion/removal testing device. Additionally, machining allowances were added on the distal and lingual surfaces. Based on the STL data, each metal abutment tooth was fabricated using cobalt-chromium powder (EOS CobaltChrome SP2, EOS, Krailling, Germany) via SLM with an additive manufacturing machine (EOSINT M270, EOS, Krailling, Germany) (*Table 1*). The particle size of the powder was about 20 µm, and the conditions for additive manufacturing were set to an irradiation rate of 0.02 mm/s and a layered thickness of 50 µm. The final preparation of metal abutment tooth involved heat-treatment according to the manufacturer's instructions. The distal and lingual surfaces of the abutment tooth were finished with a milling machine (DWX-52DCi, Roland DG, Shizuoka, Japan) and polished.

Table 1. Composition and mechanical properties of the alloys used in this study.

Manufacturing Method	Composition (mass%)*1	Mechanical properties*1	Brand Name (Manufacture)
Cast	Co: 58.3, Cr:32.0, Mo: 6.5, W: 1.5, Si: 1.0, other (C, N): <1	PS: 720 MPa, UTS: 960MPa, EL: 4%, EM: 230 Gpa, Hv: 370	Demanium GM800+ (Dentaurum)
SLM	Co: 61.8-65.8, Cr:23.7-25.7, Mo: 4.6-5.6, W: 4.9-5.9, Si: 0.8-1.2, other	PS: 850 MPa, UTS: 1,350MPa, EL: 3%	EOS Cobalt Chrome SP2 (EOS)

***1: based on the nominal values from manufacture, PS: 0.2% proof strength, UTS: Ultimate tensile strength, EL: Elongation for fracture, EM: elastic Modulus, Hv: Vicker's h.**

PREPARATION OF CLASPS

Each abutment tooth underwent scanning via a 3D scanner (D2000, 3shape) to obtain STL data. A clasp suitable for each abutment tooth was designed using the CAD software (exocad version 3.0, exocad). The Akers clasps were designed with a retentive arm on the buccal side and a bracing arm on the lingual side. Different undercuts were incorporated into the clasp arm for each abutment tooth. Specifically, retentive arms were positioned at undercuts of 0.25 mm, 0.15 mm, and 0 mm. For the 0.25 and 0.15 mm undercuts, the arm was designed to enter the undercut area of the abutment tooth halfway along length of the clasp arm. The buccal arm with 0 mm undercut was designed to run along the survey line of the abutment teeth. The clasp arm exhibited a width of 1.0 mm at the tip and 2.5 mm at the shoulder. Based on the designed clasp, each clasp was fabricated using cobalt-chromium powder (EOS CobaltChrome SP2, EOS, Krailling, Germany) via SLM with an additive manufacturing machine (EOSINT M270, EOS, Krailling, Germany). The fabricated clasps were designated as SLM-0.25, SLM-0.15, and SLM-0 to correspond with the respective undercuts. For the SLM group, the surface of the rest was positioned parallel to the platform, and the same additive manufacturing and heat-treating methods used to prepare the metal abutment teeth were used to fabricate the clasps.

As a reference, a conventional casting clasp for a 0.25-mm undercut was prepared (Cast-0.25) and denoted to the Cast group. A resin pattern (dima Print Cast Kulzer, Hanau, Germany) was made from the designed clasp data using an additive manufacturing machine for resin (NEXTDENT 5100, 3D system, 3D Systems, SC, USA). The pattern was invested in phosphate bonded investing material (rema Exakt, DENTAURUM, Ispringen, Germany) and fired in a furnace (SFB-2040, SILICONIT, Saitama, Japan). The temperature schedule was as follows: heat to 250°C at a rate of 5°C/min, hold for 60 minutes, heat to 1050°C at a rate of 5°C/min, and hold for 40 minutes. A high-frequency centrifugal casting machine (Auto Sensor MD-201, DENKO, Chiba, Japan) was used to cast cobalt-chromium alloy (Demanium GM800+, DENTAURUM, Ispringen, Germany). After casting, the specimens were minimally modified and polished using carborundum and silicone points. At this time, the retentive force was not adjusted (*Figure 1 and 2*).

MEASUREMENT OF RETENTIVE FORCE

The clasp retentive force was measured through a tensile test using a universal testing machine (Autograph AG-X/R, Shimadzu, Kyoto, Japan). The abutment tooth was placed on the testing machine so that the guide plane of the fabricated abutment tooth was parallel to the direction of insertion and removal. A load of 9.8 N was applied for 20 s when inserting the clasp onto the abutment tooth, then the clasp was removed at a crosshead speed of 50 mm/min. This procedure was repeated ten times, and the average of five values was taken as the clasp retentive force. The retentive force was measured as the initial retentive force before the repetitive insertion/removal test, and then every 1,000 insertion/removal cycle up to 10,000 cycles, for a total of 10 measurements.

REPETITIVE INSERTION/REMOVAL TEST

For this study, a special repetitive insertion/removal testing device (TDC-Ykp, Japan Mecc Tokyo, Japan) was used.[21] The clasp's repetitive insertion/removal action onto the abutment tooth was cycled a total of 10,000 cycles under a constant load of 49 N and a crosshead speed of 1,800 mm/min. The number of clasps with an undercut amount different from that of the abutment was set at 5, based on previous study.[21] The tests were conducted within a controlled environment of 37°C distilled water.

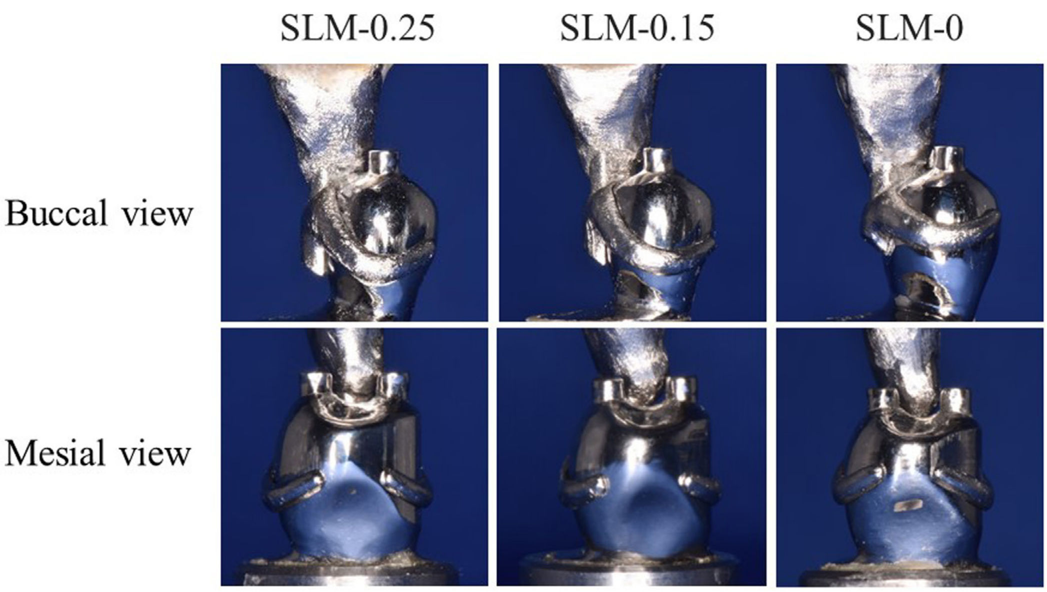

Figure 1: Photographs with clasp on abutment tooth at buccal (upper row) and mesial (lower row) viewers. In SLM-0.25, the clasp arm is run from the maximum abutment of the buccal to the undercut, and then the clasp tip is positioned at the undercut. SLM-0 is that clasp arm and tip were on the maximum abutment.

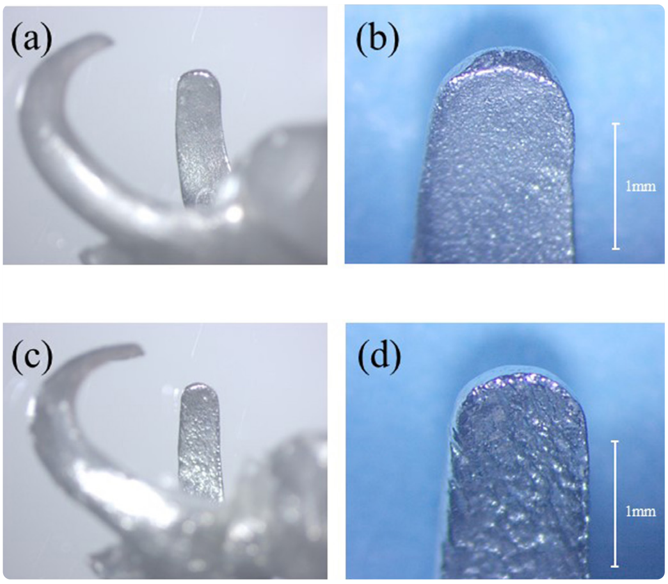

Figure 2: Photographic images of Cast and SLM-0.15 clasps and of high magnification at inner surface of clasp tip.

MEASUREMENT OF THE SURFACE ROUGHNESS

The roughness of the inner surface of the clasp tip before and after the repetitive insertion/removal test was analyzed. After ultrasonically cleaning a specimen in ethanol, an impression of the inner surface of the clasp was taken using silicone rubber impression material (Provil novo Light, Kulzer, Hanau, Germany). The impression surface was vapor-deposited with carbon (VC-100 CARBON COATER, VACUUM DEVICE, Ibaraki, Japan), and the surface roughness was measured using a three-dimensional scanning electron microscope (3D-SEM; ERA8900FE, ELIONIX, Tokyo, Japan). The measurement was conducted at an accelerating voltage of 15 kV. Within the 1.0 × 1.0 mm area of the clasp tip, five points within a 240 μm × 180 μm range were randomly selected for assessment. The resulting average surface roughness (Sa) was used to characterize the surface roughness.

SEM OBSERVATION

The clasp tip on the abutment tooth before and after the repetitive insertion/removal test was observed under the field emission scanning electron microscope (SEM; SU6600, Hitachi High-Tech Tokyo, Japan). The accelerating voltage was 15 kV.

STATISTICAL ANALYSIS

Statistical analysis was performed to the retentive force and roughness via statistical software program (SPSS, ver.25 IBM, New York, USA). For the initial retentive force, one-way analysis of variance (ANOVA) was used to compare the four conditions SLM groups (SLM-0.25, SLM-0.15, SLM-0), and Cast-0.25 followed by Bonferroni's multiple comparison test. For the comparison of retentive force every 1,000-cycle to 10,000 cycles with the initial retentive force, ANOVA was followed by the Dunnett's test. For the surface roughness of the inner surface of the clasp tip before and after the repetitive insertion/removal test, ANOVA was used to compare the four conditions, followed by Bonferroni's multiple comparison test. In addition, Student's t-test was used for each condition to compare the surface roughness before and after the repetitive insertion/removal test. To determine the surface roughness of the abutment tooth after the repetitive insertion/removal test, ANOVA was used to compare the four conditions, followed by Bonferroni's multiple comparison test. The significance level was set at 0.05.

RESULTS

INITIAL RETENTIVE FORCE

The initial retentive force was the highest in SLM-0.25, followed by Cast-0.25, SLM-0.15, and SLM-0. The corresponding mean and standard error values were 17.4 ± 0.6 N, 13.7 ± 1.1 N, and 9.2 ± 1.1 N, and 5.6 ± 0.4 N, respectively. A statistically significant difference was observed among the four conditions (ANOVA; $p<0.01$). Upon performing multiple comparisons, significant differences were observed in all combinations (Bonferroni's multiple comparison test; $p < 0.05$) (*Figure 3*).

CHANGES IN RETENTIVE FORCE AFTER REPETITIVE INSERTION/REMOVAL TEST

A statistically significant difference was observed in all four conditions when assessing the initial retentive force throughout cycles from 1,000-cycle to 10,000 cycles (ANOVA; $p<0.01$). As a result of the multiple comparison test, there was a significant difference between the initial retentive force and retentive force after 2,000 cycles for Cast-0.25 and SLM-0.25 ($p=0.034$ and $p=0.002$, respectively), and the initial retentive force and retentive force after 1,000 cycles for SLM-0 ($p=0.021$), and initial retentive force and retentive force after 5,000 cycles for SLM-0.15 ($p=0.032$). The retentive force after 10,000 repetitive insertion/removal cycles was the highest at Cast-0.25, followed by SLM-0.25, SLM-0.15, and SLM-0, with values of 9.1 ± 1.0, 8.5 ± 0.8, 5.2 ± 0.7, and 2.3 ± 0.4 N, respectively. (*Figure 4*).

SURFACE ROUGHNESS OF THE INNER CLASP SURFACE

The surface roughness of the inner clasp surface before the repetitive insertion/removal test followed the order of SLM-0.25, SLM-0.15, SLM-0, and Cast-0.25, with respective values of 3.2 ± 0.3 μm, 2.5 ± 0.4 μm, 2.4 ± 0.3 μm, and 1.1 ± 0.1 μm. A statistically significant difference was observed among the four conditions (ANOVA; $p<0.01$). The multiple comparison test showed a significant difference between Cast-0.25 and all three SLM conditions, SLM-0.25 and SLM-0.15, and SLM-0.25 and SLM-0 (Bonferroni's multiple comparison test; $p<0.01$).

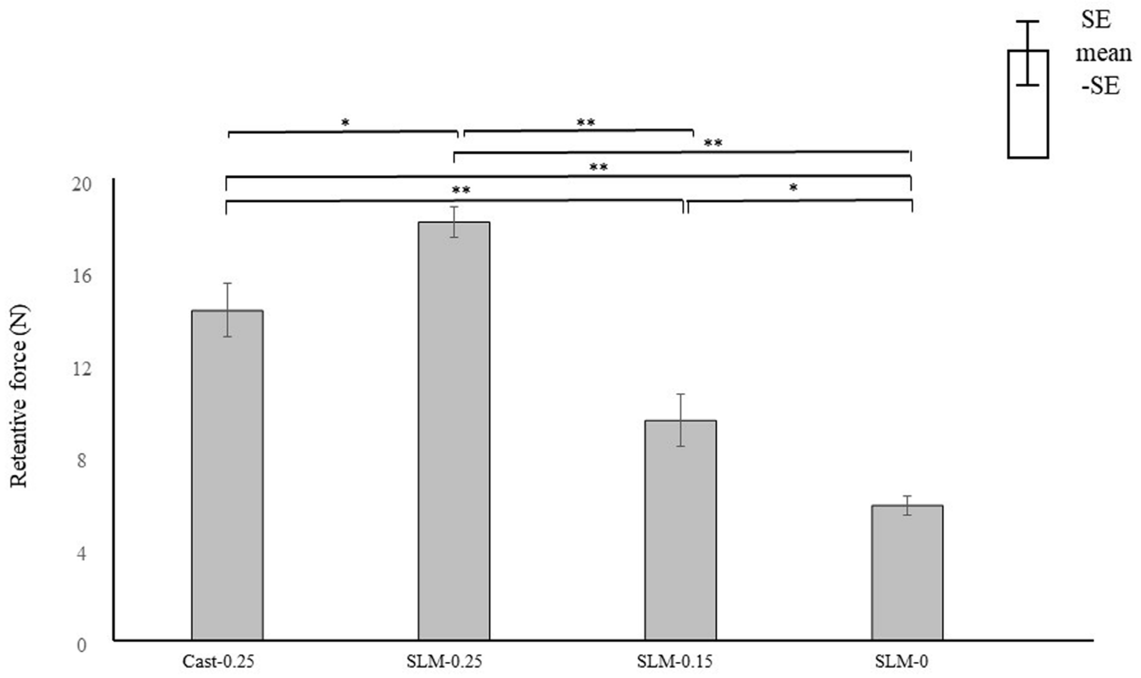

Figure 3: Initial retention force of clasp for Cast-0.25, SLM-0.25, SLM-0.15, and SLM-0. There are statistically significant differences among all groups (Bonferroni's multiple comparison test; *: P<0.05, **: P<0.01).

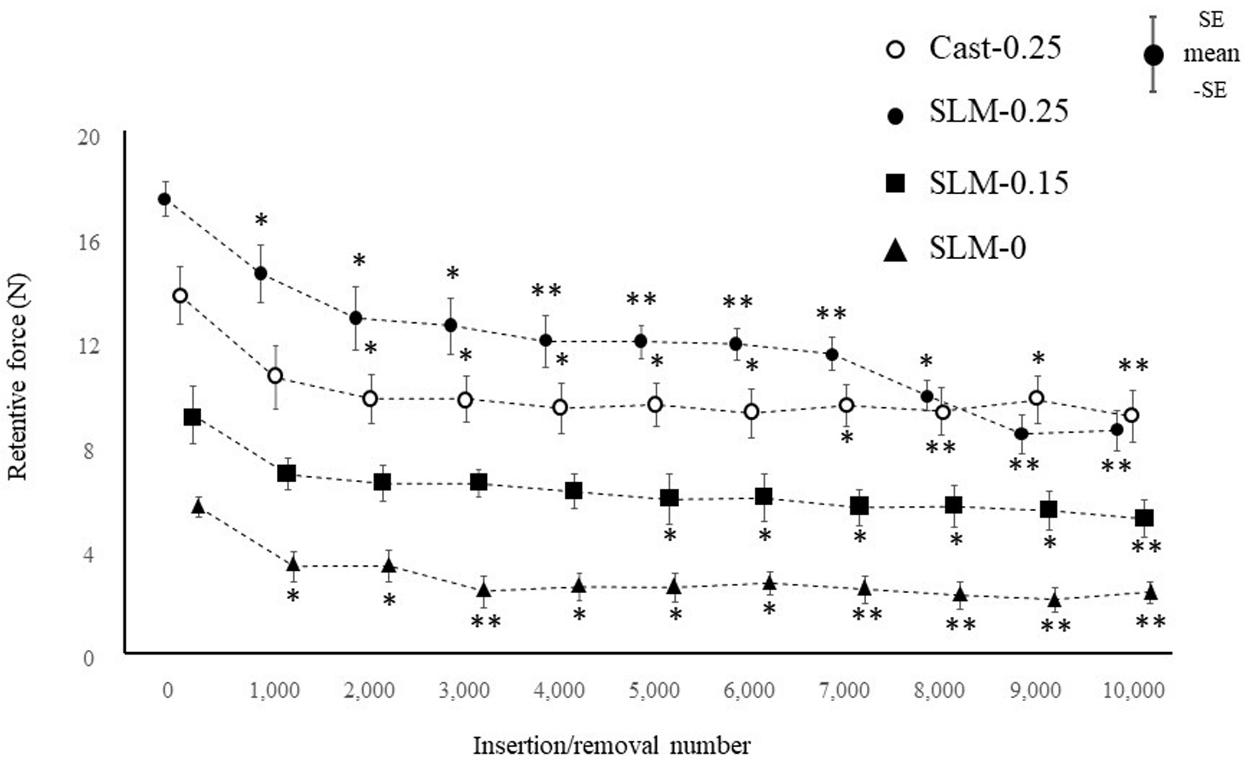

Figure 4: Change in the retention forces for Cast-0.25, SLM-0.25, SLM-0.15, and SLM-0 during the repetitive insertion/removal test. The "*" and "**" showed the significant differences between the initial retention force and the retention force after the number of repetitive insertion/removal cycles. Dunnett's test; *: P<0.05, **: P<0.01

Regarding the surface roughness of the inner clasp surface after the repetitive insertion/removal test, a statistically significant difference was observed among the four conditions (ANOVA; p<0.01). Further analysis through the multiple comparison test demonstrated a significant difference between Cast-0.25 and SLM-0.25, Cast-0.25 and SLM-0, SLM-0.25 and SLM-0.15 (Bonferroni's multiple comparison test; p<0.01).

The surface roughness of the inner clasp after repetitive insertion/removal test displayed a reduction across all four conditions. A significant difference was observed between the roughness before and after testing (Student's t-test; $p<0.01$) *(Figures 5 and 6)*.

SEM OBSERVATION OF THE CLASP TIP

SEM images prior to the repetitive insertion/removal test revealed a notably improved fit of clasps across all three SLM conditions when compared to clasps from the Cast group. Following repetitive insertion/removal testing, the Cast group displayed increased gaps at the clasp tip compared to the pre-test state. However, there were no noticeable changes before and after repetitive insertion/removal test for SLM clasps across all three conditions *(Figure 7)*.

DISCUSSION

RETENTION FORCE

The mechanical properties of clasps fabricated with SLM differed from those produced by the casting method. Existing literatures have noted that clasps fabricated by SLM exhibited greater 0.2% yield strength and bending strength.[22-24] Moreover, the initial retentive force for SLM fabricated clasps surpassed that of cast clasps with the same undercut.[12] In this study, SLM-0.25 had the largest initial retentive force, and there was a significant difference between SLM-0.25 and Cast-0.25. These results align with prior research, suggesting that SLM was an appropriate fabrication method for clasps requiring large retention.

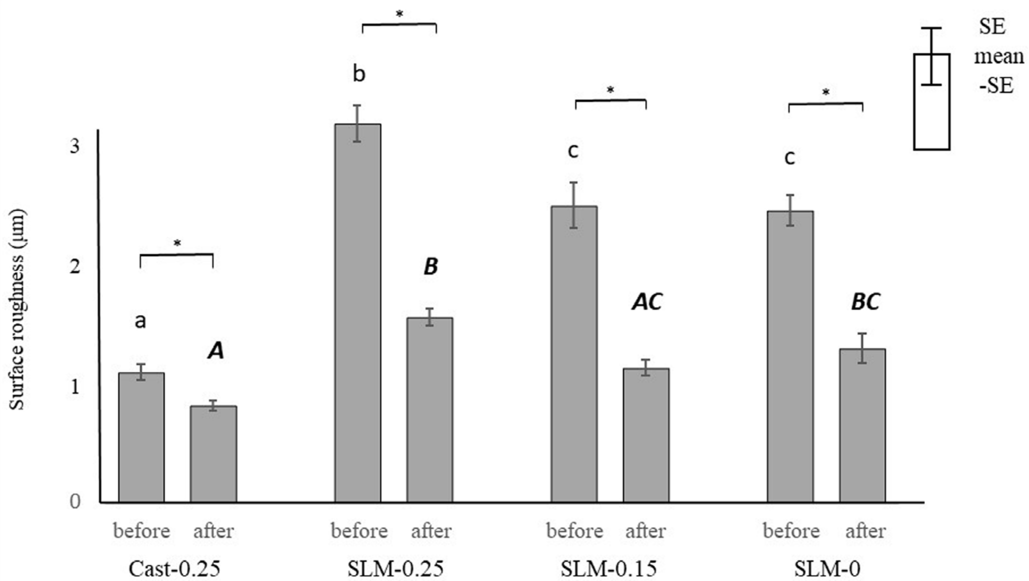

Figure 5: Surface roughness of the inner clasp before and after repetitive insertion/removal test. The "*" indicated a significant difference of surface roughness between before and after repetitive insertion/removal test (Student's t-test;*:$P<0.01$), and the lowercase and uppercase indicated the significant difference among the specimens before repetitive test and among the specimens after repetitive test, respectively (Bonferroni's multiple comparison test; $P<0.01$).

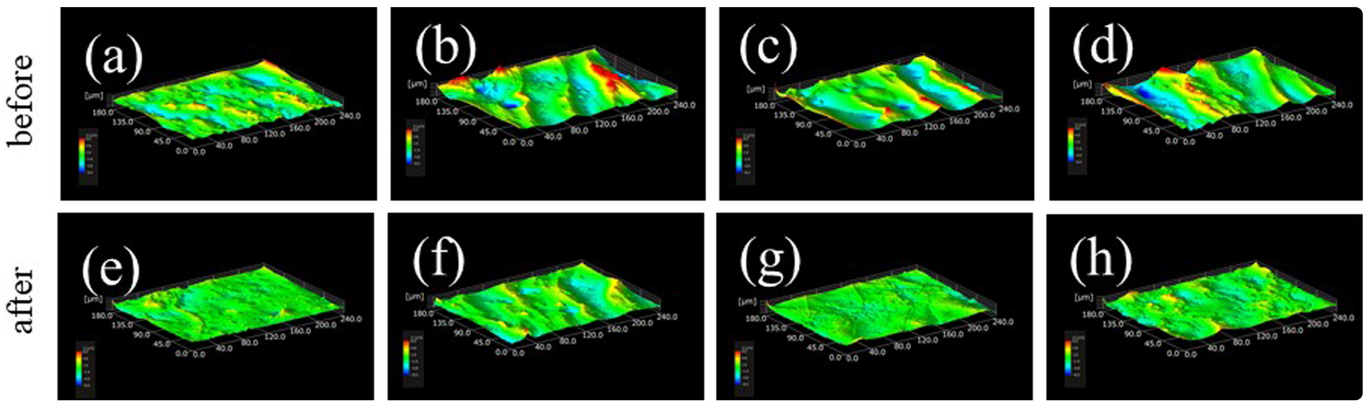

Figure 6: Color mapping images of surface roughness in each specimen before (upper row) and after (lower row) repetitive insertion/removal test. (a) and (e) Cast-0.25, (b) and (f) SLM-0.25, (c) and (g) SLM-0.15, (d) and (h) SLM-0.

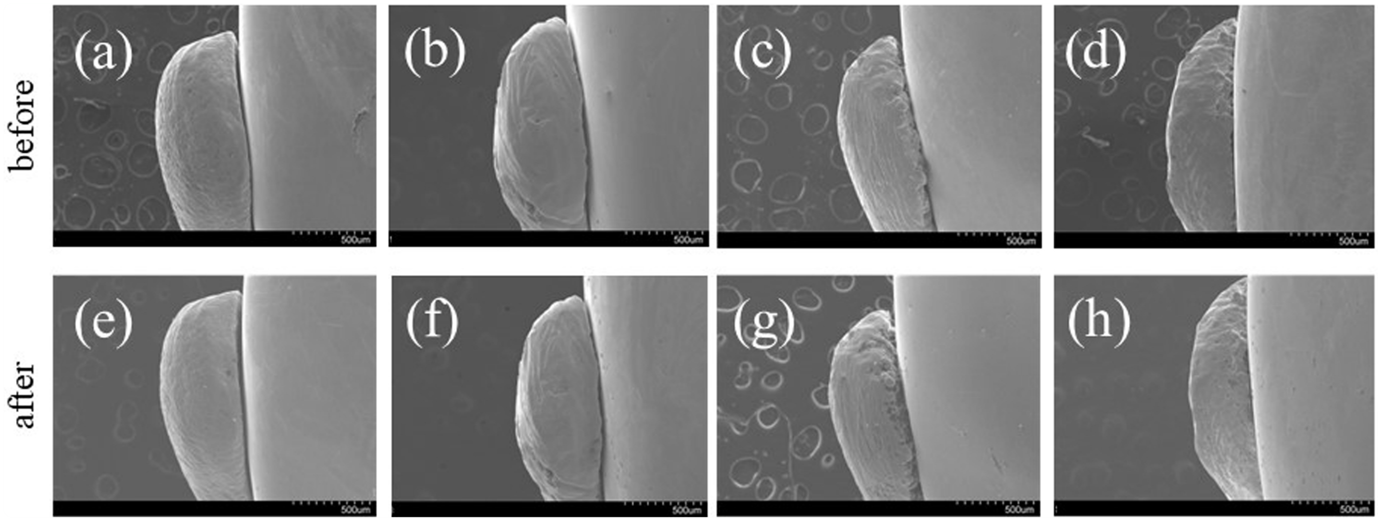

Figure 7: SEM images of clasp tip on the abutment tooth before (upper row) and after (lower row) repetitive insertion/removal test. (a) and (e) Cast-0.25, (b) and (f) SLM-0.25, (c) and (g) SLM-0.15, (d) and (h) SLM-0.

Sato *et al*. reported that the appropriate retentive force exerted by the clasp was in the range of 5-10 N.[5] The initial retentive force exhibited by SLM-0.15 and SLM-0 effectively aligns within this range, suggesting an undercut within 0 to 0.1 mm yields an initial retentive force within the desired range. In contrast, both Cast-0.25 and SLM-0.25 yielded retentive forces greater than 10 N, thus deviating from the appropriate range. Therefore, when dealing with a 0.25 mm undercut, it is necessary to adjust the clasp tip for both Cast and SLM clasps.

The 1,000 cycles could correspond to a year on three times repetitive of denture per day.[21] A significant difference was observed between the initial retentive force and retentive force after 2,000 repetitive insertion/removal cycles in the Cast-0.25 group. In our previous report, a decrease of retention force of clasp after the test was similar to the obtained result using same testing device.[21] Patterns in the retentive force changes followed a similar were comparable in both Cast-0.25 and SLM-0.25. Previous studies reported that the retentive force of SLM clasps remains more stable than cast clasps.[15,16] Typically, clasp designs feature retentive arms on both buccal and lingual sides,[4,21,25,26] facilitating easy adjustment of retention forces. However, in this study, clasps were exclusively designed with the retentive arm on the buccal side without adjustments after fabrication; therefore, the retentive force showed different values in reports.[27,28]

The experimental condition of SLM-0 was designed based on the hypothesis that a well-fitted SLM clasp could yield sufficient retentive force even without position the clasp tip within the undercut area. However, SLM-0 displayed an earlier reduction in retentive force, with a significant reduction in retentive force after 1,000 repetitions, in comparison to the initial retentive force. When the clasp tip was not within the undercut area, retention primarily relies on friction between the clasp tip and abutment tooth during insertion/removal cyclic test. Consequently, early wear of the inner clasp surface may affect the retentive force. These results indicated that although SLM-0 had an appropriate initial retentive force, its practical applicability in clinical settings is challenging.

In contrast, SLM-0.15 had an initial retentive force in the range of 5-10N, similar to SLM-0, and showed a significant difference in retentive force after 5,000 cycles. These findings suggest that SLM-0.15 maintains stability in retentive force across repetitive insertion/removal cycles, with the least likelihood of experiencing changes within the parameters set in this study. After 10,000 cycles, the retentive force of SLM-0.15 was about 5 N, retaining satisfactory retention during repetitive insertion/removal cycles. The decline in the retentive force of SLM clasps varied depending on the amount of undercut. Consequently, the null hypothesis that the amount of undercut on the abutment tooth did not affect the retention forces of clasps fabricated by SLM, was rejected.

EFFECTS OF CLASP AND ABUTMENT TOOTH

The surface roughness of clasps fabricated via SLM has been reported to be affected by factors such as the unmelted metal powders and stacking conditions.[25] Furthermore, the SLM-fabricated clasp had demonstrated larger roughness compared to cast-fabricated clasps.[10,29] The molding angle during laser-melting fabrication has been reported to affect the internal defects and the surface roughness of products fabricated by SLM.[11,30] Within this study, among the three conditions manufactured by SLM, SLM-0.25 had the largest surface roughness, and a significant difference was observed between SLM-0.15 and SLM-0.

While the position of the rest concerning the platform remained constant across all conditions, the angle of the clasp tip varied according to the undercut.

The SEM images, as shown in Figure 7, confirmed that the outer surface on the clasp fabricated by SLM conformed to the abutment tooth but exhibited some non-conforming areas due to residual metal powder and manufacturing inconsistencies. For Cast-0.25, a gap was evident between the abutment tooth and the lower edge of the clasp tip. These findings indicated that claps made by the conventional casting technique may require adjustment after casting due to poor fit accuracy and unstable retention. The study investigated changes in retentive force during repetitive insertion/removal and subsequently observed micro-deformation of clasp tip. Clasp deformation was observed on the clasp tip far from the contact point on the abutment tooth when the clasp was passed through maximum abutment ridge into the undercut zone after repetitive insertion/removal. In clinical situations, enhancing clasp adaptation to achieve suitable retentive force is typically achieved by adjusting the clasp arm and polishing the inner surface.[18,31] However, if SLM clasps are adjusted in the same manner as cast clasps to enhance retentive force, it could compromise the excellent fit attributes inherent to SLM fabrication. In this study, SLM-0.15 and SLM-0 demonstrated sufficient retentive force even with small undercuts, suggesting that these clasps can be clinically applied with good fit without any adjustments.

Following repetitive insertion/removal tests, the surface roughness on inner surface of the SLM clasps decreased, and a significant difference was indicated under all conditions between the roughness before and after testing. An examination of the clasp tip showed a gap for Cast-0.25 after repetitive insertion/removal test, but no significant change was observed on the SLM clasps under all conditions. The initial stage of roughness on the inner side of the clasp, due to unmelted powder, encompasses small contact points, followed by a decrease in surface roughness due to wear from the repetitive insertion/removal test. This results in increased friction between the abutment tooth and the clasp.

Although the SLM specimen made of cobalt-chromium alloy have been reported to possess similar elastic moduli as Cast specimens, they exhibit larger proof strength and tensile strength.[24] Clasps made with alloys of large elastic moduli yield greater retentive force due to the large amount of elastic deformation within the undercut towards the maximum abutment range. In addition, the friction between the clasp and the abutment tooth plays a role in the retentive force. The retentive force during early stages was enhanced by the slight decrease in surface roughness and improved contact area with the abutment during early repetitive insertion/removal tests. Clasps fabricated by SLM could achieve a suitable retentive force due to superior contact area fit and large elastic moduli, even with small elastic deformation through the undercut towards the maximum abutment. Therefore, the change in retentive force during repetitive insertion/removal test could be influenced not by the difference in elastic moduli between SLM and Cast, but by the difference in wear on the inner surface of clasp and the difference in contact fit due to manufacturing. However, Akers clasp designs with different undercuts entail clasp arms of varying lengths. This may affect the retentive force due to clasp deflections and a larger contact area between the clasp and the abutment tooth. Also, in the limitation of this study, large rigidity in cobalt-chromium alloy was used for the abutment tooth and clasp. As a result, future investigations should investigate the interaction between the clasp arm length and the fitting area between the clasp arm and the abutment tooth, and materials, zirconia and resin composite, or abutment tooth.

CONCLUSION

This study investigated the effects of undercut depths on metal abutment teeth on the retention force of Akers clasp fabricated by SLM. The results can be summarized as follows.

1. The initial retention force of Akers clasps fabricated by SLM was greater on abutments with larger undercuts.
2. The initial retentive force of SLM-0.15 fell within the appropriate range of 5 N to 10 N, and this optimal range was also maintained after subjecting the clasps to 10,000 cycles of repetitive insertion/removal tests.
3. The surface roughness of the inner clasp surface was greater for SLM fabricated clasps compared to those made through casting.

In conclusion, Akers clasps for removal partial dentures could be successfully fabricated through SLM to control the retentive force by adjusting the amount of undercut. Moreover, these SLM-fabricated clasps offer a superior fit compared to cast claps.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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