Evaluation of Resin Clasps with Different Design by Retentive Force

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Abstract
The aim of the present study was to apply acrylic resin for a removable partial denture (RPD) with resin clasps. The present study evaluated the changes in retentive forces of resin clasps with different designs composed of acrylic resin or polyester by repeated insertion/removal motion.

Two resin clasp designs (length: 7.5 mm, width: 7.5 mm or 10 mm, thickness: 1.5 mm) made of acrylic resin or polyester (control) were used. An abutment tooth simulating the maxillary first premolar was prepared by using an 18-8 stainless steel model. The amount of undercut of the retentive arms was set at 0.5 mm, with half of the undercut area at the far zone as the contact surface. The initial retentive force and retentive force for each test specimen were measured. The changes of retentive force until 10,000 insertion/removal cycles were measured by an insertion/removal testing apparatus placed in distilled water at 37°C and an insertion load to the abutment tooth of 9.8 N.

The initial retentive force was not significantly different between each test specimen. During 9.001–9.015 and 10.001–10.015 insertion/removal cycles, the retentive force of acrylic resin clasps with width of 10 mm was significantly higher than that of polyester clasps with width of 7.5 mm (P<0.05).

Our present study may suggest that an RPD with resin clasps composed of acrylic resin with dimensions of length of 7.5 mm, width of 10 mm, and thickness of 1.5 mm with half of the undercut area at the far zone as the contact surface has the potential for use in clinical application.

Keywords:
resin clasp, clasp design, initial retentive force, retentive force, non-metal clasp denture

Introduction
Removable partial dentures (RPDs) with resin clasps are widely used in clinical practice. RPDs with resin clasps have superior esthetic performance to metal clasps and high elasticity to allow the same degree of retentive force as metal clasps (1–4). RPDs with resin clasps are fabricated with thermoplastic denture base resin, the bending properties of which influence the retentive force, fitness, and transmission of stress to the abutment teeth (5–8). For retentive force, past studies show that 5–10 N per tooth is required for the retention device of an RPD with wire clasps (9, 10). Although some studies investigated the length, width, and thickness in the design of resin clasps (11–13), the optimal design for resin clasps in RPD with resin clasps was not clarified.

Acrylic resin has some advantages compared with polyester, such as greater ease of relining or other repairs of denture bases (14, 15) and better grindability (16). The final aim of our project was to apply acrylic resin to RPD with resin clasps in the clinical situation. Our previous study investigated the possibilities of four types of acrylic denture base materials in resin clasps by using three-point flexural tests and cantilever beam tests and suggested some acrylic
resins have the potential to be used in RPDs with resin clasps (17). However, some studies suggested that resin clasps made from acrylic resin are difficult to insert and remove from the abutment tooth and have a high risk of fracture (18, 19). Our previous study investigated the initial retentive force and retentive force of acrylic resin clasps to an abutment tooth with measurements of length of 7.5 mm, width of 10 mm, and thickness of 1.5 mm with the undercut area at the near and far zones as the contact surface, and acrylic resin fractured until 3,000 insertion/removal cycles. To apply acrylic resin for RPD with resin clasps, it is essential to investigate the initial retentive force and retentive force using resin clasps with a modified design.

The hypothesis of the present study was that if resin clasps made of acrylic resin do not fracture and maintain a retentive force >5 N after fatigue testing, then these clasps have the potential to be applied in RPDs with resin clasps. In the present study, we evaluated the changes in retentive forces of resin clasps with different designs made by acrylic resin or polyester in repeated insertion/removal motion.

Materials and Methods

Preliminary experiment

To determine the resin clasp design in the main experiment, the initial retentive force was measured from six resin clasp designs. The six resin clasp designs consisted of length of 7.5 mm, width of 5 mm, 7.5 mm, or 10 mm, and thickness of 1.0 mm or 1.5 mm. Pro Impact (GC Corporation, Tokyo, Japan) was used for acrylic resin clasps, and EstheShot Bright (i-Cast Inc., Kyoto, Japan) was used for polyester clasps (set as the control) (Table 1). Three test specimens were fabricated for each of the six resin clasp designs and two materials.

The nodules and burs of the acrylic resin and polyester clasp specimens were carefully polished. An abutment tooth simulating the maxillary first premolar (diameter of 7.5 mm, height of 8 mm, and curvature radius of 5 mm) was prepared by using an I8–8 stainless steel model. The amount of undercut of the retentive arms was set at 0.5 mm, with half of the undercut area at the far zone as the contact surface. The reciprocal arm was set on the survey line (Fig. 1). The working cast was fabricated with hardened plaster (New Fujirock; GC Corporation) after taking an impression of the metal model using silicon impression material (High

Table 1  Test materials used in the present study

| Constituent | Material (abbreviation) | Manufacturer       | Processing method         | Lot No.          |
|-------------|-------------------------|--------------------|---------------------------|-----------------|
| Polyester   | EstheShot Bright (ESB)  | i-CAST, Kyoto, Japan | Injection molding         | 7D4761610       |
| Acrylic     | Pro Impact (PI)         | GC, Tokyo, Japan   | Heat-polymerizing         | Powder: 1711172 |
|             |                         |                    |                           | Liquid: 1709011 |

Fig. 1. Overview of the resin clasp prepared for the retentive test

The resin clasp measured 7.5 mm in length, 7.5 mm or 10 mm in width, and 1.5 mm in thickness. The amount of undercut of the retentive arms was set at 0.5 mm, with half of the undercut area at the far zone as the contact surface. The reciprocal arm was set on the survey line.
Silicone II; Denken-Highdental Co., Ltd., Kyoto, Japan). Test specimens were fabricated from acrylic resin or polyester according to the manufacturer’s instructions.

The initial retentive force for each test specimen was measured 15 times using a tensile test apparatus (EZ-S-200N, Shimadzu Corporation, Kyoto, Japan) at a crosshead speed of 50 mm/min (20–23), and the mean value of initial retentive force for each test specimen was calculated.

Table 2 shows comparisons of the initial retentive force in the six resin clasp designs composed of acrylic resin or polyester. According to our preliminary results, the two resin clasp designs with the highest initial retentive force had a length of 7.5 mm, width of 7.5 mm or 10 mm, and thickness of 1.5 mm and were subsequently used in the main experiment.

### Table 2: Comparison of the initial retentive force between each type of resin clasp in the preliminary experiment

| material (length (mm), width (mm), thickness (mm)) | initial retentive force (N) |
|--------------------------------------------------|-----------------------------|
| Acrylic resin (7.5, 5, 1.0)                       | 4.0 ± 0.1                   |
| Acrylic resin (7.5, 5, 1.5)                       | 4.3 ± 0.3                   |
| Acrylic resin (7.5, 7.5, 1.0)                     | 4.9 ± 0.5                   |
| Acrylic resin (7.5, 7.5, 1.5)                     | 9.9 ± 0.9                   |
| Acrylic resin (7.5, 10, 1.0)                      | 6.3 ± 1.0                   |
| Acrylic resin (7.5, 10, 1.5)                      | 10.6 ± 2.3                  |
| Polyester (7.5, 5, 1.0)                           | 3.7 ± 0.3                   |
| Polyester (7.5, 5, 1.5)                           | 4.5 ± 0.2                   |
| Polyester (7.5, 7.5, 1.0)                         | 4.7 ± 0.2                   |
| Polyester (7.5, 7.5, 1.5)                         | 8.3 ± 0.9                   |
| Polyester (7.5, 10, 1.0)                          | 5.4 ± 0.3                   |
| Polyester (7.5, 10, 1.5)                          | 9.3 ± 1.3                   |

| Mean ± SD                                       |

The changes of retentive force until 10,000 insertion/removal cycles to simulate the clinical condition [approximately the number of insertion/removal cycles over 9 years (3 times/day × 365 days × 9 years = 9,855 insertion/removal cycles)] were measured by an insertion/removal testing apparatus (JM 100; MECC Co., Ltd., Tokyo, Japan) placed in distilled water at 37°C and an insertion load to the abutment tooth of 9.8 N to simulate the placement and removal of an RPD in accordance with previous studies (20–23). The mean retentive force was measured at 1,001–1.015, 2,001–2.015, 3,001–3.015, 4,001–4.015, 5,001–5.015, 6,001–6.015,
7,001–7,015, 8,001–8,015, 9,001–9,015, and 10,001–10,015 insertion/removal cycles as described by Nakata et al.(21). The retentive force was calculated using the same formula used to calculate the initial retentive force.

**Statistical analysis**

All data are presented as mean values and standard deviation. The Friedman test with Bonferroni correction was used to compare initial retentive force and retentive force within experiments. P values < 0.05 were considered significant.

**Results**

**Initial retentive force**

Fig. 2 shows comparisons of the initial retentive force of acrylic resin clasps with width of 7.5 mm or 10 mm and polyester clasps with width of 7.5 mm or 10 mm. The initial retentive forces of acrylic resin clasps with widths of 7.5 mm and 10 mm were 9.9 ± 0.9 N and 10.6 ± 2.3 N, respectively, and those of polyester clasps with widths of 7.5 mm and 10 mm were 8.3 ± 0.3 N and 9.3 ± 1.3 N, respectively. There was no significant difference in the initial retentive force between each test specimen.

**Retentive force after fatigue tests**

Fig. 3 shows comparisons of the retentive force of acrylic resin clasps with width of 7.5 mm or 10 mm and polyester clasps with width of 7.5 mm or 10 mm. None of the test specimens had fractured after 10,000 insertion/removal cycles.

The final retentive forces of acrylic resin clasps with widths of 7.5 mm and 10 mm after 10,000 insertion/removal cycles were 4.8 ± 1.1 N and 6.0 ± 0.7 N, respectively, and those of polyester clasps with widths of 7.5 mm and 10 mm were 3.6 ± 0.5 N and 4.4 ± 1.1 N, respectively. During 9,001–9015 and 10,001–10,015 insertion/removal cycles, the retentive forces of acrylic resin clasps with width of 10 mm were significantly higher than that of polyester clasps with width of 7.5 mm (P < 0.05).

**Discussion**

The present study evaluated the modified design of resin clasps made of acrylic resin and polyester by investigating the initial retentive force and retentive force. In the main experiment, the initial retentive force and retentive force after fatigue testing were evaluated in two resin clasp designs (length: 7.5 mm, width: 7.5 mm or 10 mm, thickness: 1.5 mm).

Our present results showed that the initial retentive force and retentive force were not significantly dependent on material used (acrylic resin and polyester). In the clinical setting, Fueki et al. showed the relationship between fracture and material used for RPD with resin clasps(1). In the experimental setting, Osada et al. reported that some conditions induced fracture during fatigue testing(21). Our previous study also showed that acrylic resin fractured until
3,000 insertion/removal cycles using an abutment tooth with dimensions of length of 7.5 mm, width of 10 mm, and thickness of 1.5 mm with the undercut area at the near and far zones as the contact surface (24). In the present study, we used an abutment tooth with dimensions of length of 7.5 mm, width of 10 mm, and thickness of 1.5 mm with half of the undercut area at the far zone as the contact surface and test specimens did not fracture until 10,000 insertion/removal cycles. Our results suggested that resin clasp design using about half of the undercut area as the contact surface was useful to reduce fracture in the resin clasp. However, since fracture of the resin clasp is affected by various factors, further studies are needed to confirm the optimal design of the resin clasp.

Concerning the retentive force, acrylic resin clasps with width of 10 mm had significantly higher retentive force than polyester clasps with a width of 7.5 mm during 9,001–9,015 and 10,001–10,015 insertion/removal cycles. Another study also compared retentive force until 10,000 insertion/removal cycles between different materials and showed no significant differences (25). Since clasp design in the present study was different from that of the previous study (25), our present results suggested that clasp design may be the main factor that affects retentive force. Furthermore, past studies showed that retentive force of 5–10 N per tooth was necessary for RPDs with wire clasps (9, 10). In the present study, although the retentive force of all test specimens was >5 N until 6,000 insertion/removal cycles, only acrylic resin clasps with width of 10 mm maintained a retentive force >5 N until 10,000 insertion/removal cycles. In addition, the initial retentive force of all test specimens was >5 N. Our present study may suggest that acrylic resin clasps with dimensions of length of 7.5 mm, width of 10 mm, and thickness of 1.5 mm with half of the undercut area at the far zone as the contact surface is useful for clinical application as the resin clasp in RDPs. However, Torii et al. utilized the same equipment but resin clasps with different designs and materials and showed that the retentive force remained >5 N until 10,000 insertion/removal cycles (25). Since the retentive force of the resin clasp is affected by various factors, further studies are needed to investigate the optimal material for the resin clasp.

Fig. 3. Comparison of retentive force up to 10,000 insertion/removal cycles between acrylic resin clasps with width of 7.5 mm or 10 mm and polyester clasps with width of 7.5 mm or 10 mm.

*P<0.05: Friedman test with Bonferroni correction.
As a limitation of this study, we evaluated only two dental materials (acrylic resin and polyester). Since other acrylic resins (e.g., ACRY-TONE) have the potential for use in RPDs with resin clasps, further studies of other dental materials are needed to determine the optimal material for resin clasp.

In conclusion, our results suggested that resin clasps composed of acrylic resin with half of the undercut area at the far zone as the contact surface may have the potential for clinical application as RPDs with resin clasps.

**Conflict of interest**

The authors declare that they have no competing financial interests.

**References**

1. Fueki K, Ohkubo C, Yatabe M, et al.: Clinical application of removable partial dentures using thermoplastic resin – Part I: definition and indication of non-metal clasp dentures. J Prosthodont Res, 58: 3–10, 2014.

2. Fueki K, Ohkubo C, Yatabe M, et al.: Clinical application of removable partial dentures using thermoplastic resin. Part II: Material properties and clinical features of non-metal clasp dentures. J Prosthodont Res, 58: 71–84, 2014.

3. Kuwahara K, Nagahara F, Kitahara K, et al.: A case of using non-metal clasp partial denture for the patient with the metal allergy. Nihon Univ J Oral Sci, 30: 134–139, 2004.

4. Takahashi Y, Hamanaka I, Shimizu H.: Effect of thermal shock on mechanical properties of injection-molded thermoplastic denture base resins. Acta Odontol Scand, 70: 297–302, 2012.

5. Wada J, Fueki K, Yatabe M, et al.: A comparison of the fitting accuracy of thermoplastic denture base resins used in non-metal clasp dentures to a conventional heat cured acrylic resin. Acta Odontol Scand, 73: 33–7, 2015.

6. Wadachi J, Sato M, Igarashi Y.: Evaluation of the rigidity of dentures made of injection-molded materials, Dent Mater J, 32: 508–11, 2013.

7. Nagakura M, Tanimoto Y, Nishiyama N.: Fabrication and physical properties of glass-fiber-reinforced thermoplastics for non-metal-clasp dentures, J Biomed Mater Res, 105: 2254–2260, 2017.

8. Yoda N, Watanabe M, Suenaga H, et al.: Biomechanical investigation of the “non-clasp denture” based on the load exerted on abutment teeth and under the denture base, Ann Jpn Prosthodont Soc, 4: 183–192, 2012.

9. Korber KH. Konuskronen.: 5th ed Hühlig: Heidelberg, 64–90, 1983.

10. Frank RP, Nicholls JL: A study of the flexibility of wrought wire clasps, J Prosthet Dent, 45: 259–67, 1981.

11. Hirota M, Shimpo H, Suzuki Y, et al.: Influence of metal rest in a non-metal clasp denture on pressure distribution to soft tissue. Ann Jpn Prosthodont Soc, 4: 193–200, 2012.

12. Taguchi Y, Shimamura I, Sakurai K: Effect of buccal part designs of polyamide resin partial removable dental prothesis on retentive force, J Prosthodont Res, 55: 44–7, 2011.

13. Kaplan P. Flexible removable partial dentures: Design and clasp concepts, Dent Today, 27: 120: 122–123, 2008.

14. Katsumata Y, Hojo S, Hamano N, et al.: Bonding strength of autopolymerizing resin to nylon denture base polymer, Dent Mater J, 28: 409–18, 2009.

15. Hamanaka I, Shimizu H, Takahashi Y.: Shear bond strength of an autopolymerizing repair resin to injection-molded thermoplastic denture base resins, Acta Odontol Scand, 71: 1250–4, 2013.

16. Kawara M, Iwata Y, Iwasaki M, et al.: Scratch test of thermoplastic denture base resins for non-metal clasp dentures, J Prosthodont Res, 58: 35–40, 2014.

17. Iwata Y.: Assessment of clasp design and flexural properties of acrylic denture base materials for use in non-metal clasp dentures, J Prosthodont Res, 60: 114–22, 2016.

18. Takabayashi Y.: Characteristics of denture thermoplastic resins for non-metal clasp dentures, Dent Mater J, 29: 353–361, 2010.

19. Hamanaka I, Takahashi Y, Shimizu H.: Mechanical properties of injection-molded thermoplastic denture base resins, Acta Odontol Scand, 69: 75–79, 2011.

20. Tokue A, Hayakawa T, Ohkubo C.: Fatigue resistance and retentive force of cast clasps treated by shot peening, J Prosthodont Res, 57: 186–94, 2013.

21. Nakata T, Shimpo H, Ohkubo C.: Clasp fabrication using one-process molding by repeated laser sintering and high-speed milling, J Prosthodont Res, 61: 276–282, 2017.

22. Shimpo H.: Effect of arm design and chemical polishing on retentive force of cast titanium alloy clasps, J Prosthodont, 17: 300–307, 2018.

23. Osada H, Shimpo H, Hayakawa T, et al.: Influence of thickness and undercut of thermoplastic resin clasps on retentive force, Dent Mater J, 32:381–9, 2013.

24. Takeuchi H, Iwata Y, Nakata T et al.: Assessment of retentive force of the resin clasp using various materials, Nihon Univ J Oral sci, In press, 2018.

25. Torii M, Nakata T, Takahashi K et al.: Fitness and retentive force of cobalt-chromium alloy clasps fabricated with repeated laser sintering and milling. J Prosthodont Res, 62: 342–6, 2018.