Examination of inter-rater and intra-rater reliability during retentive force measurement of different clasps using the developed small-sized retentive force measurement device

CURRENT STATUS: UNDER REVIEW

Hitoshi AKIYAMA
Nippon Dental University Hospital at Tokyo

Maiko SAKAMOTO
The Nippon Dental University Hospital, Tokyo, JAPAN

Ryoichi AKAMA
The Nippon Dental University Hospital, Tokyo, JAPAN

Jun TAKEI
The Nippon Dental University Hospital, Tokyo, JAPAN

DOI:
10.21203/rs.3.rs-16820/v1

SUBJECT AREAS
Dentistry

KEYWORDS
Dental abutment, Prosthesis retention, Removable partial denture, Dental clasp, Intraclass correlation coefficient
Abstract
The purpose of the present study is to develop a small-sized retentive force measurement device that can easily measure the retentive force of a clasp used for a removable partial denture in daily clinical practice, and it is to examine the inter-rater and intra-rater reliability. A small-sized retentive force measurement device that can be easily measured in clinic has been developed. Using commercially available hard plaster cast, a skilled dental technician has made 10 types of cast clasps used in clinical practice using conventional techniques. There were 3 assessors who measured the retentive force of 10 types of cast clasps. In order to confirm the reliability, the intra-class correlation coefficients ICC (1,1) and ICC (1,3) of the 3 assessors were calculated, and the reliability within the assessor was examined. Further, the inter-class correlation coefficients ICC (3,1) and ICC (3,3) were calculated, and the reliability between the measurers was examined. The intra-class correlation coefficients of 3 assessors are as follows: assessor 1 has ICC (1,1) = 0.971, ICC (1,3) = 0.990, assessor 2 has ICC (1,1) = 0.967, ICC (1,3) = 0.989, assessor 3 has ICC (1,1) = 0.962, ICC (1,3) = 0.987. The inter-class correlation coefficients of 3 assessors are as follows: ICC (3,1) = 0.993, ICC (3,3) = 0.998. From the evaluation standard of the intraclass correlation coefficients of reliability value by ICC, it was evaluated as almost perfect and high reproducibility was confirmed. The developed small-sized retentive force measurement device has reproducibility within and between the assessors.

Introduction
In a treatment aiming for the functional recovery of the masticatory system of partially edentulous patient, intraoral installment of prosthetic devices functioning as artificial organs is often used. From the design of removable partial denture considering occlusal pressure distribution, the design process of a removable partial denture consists of rests, major connectors, minor connectors, denture base, and retainers. Location of the retention portion of the clasp is determined by the abutment tooth contour at the retention areas [1]. The clasp of a removable partial denture is generally made of 0.25 mm, 0.50 mm, and 0.75 mm undercuts for near and far zones [2]. Circumferential clasps are the most frequently used direct retainers and the long term success of removable partial dentures
depends on properties of clasps like design of clasp arm, condition of the abutment tooth, and rigidity [3]. The retentive force is the force that works when the removable partial denture is removed, and it is necessary that an appropriate force be applied to the abutment tooth. Unfortunately, it is often the case where an inadequate denture design or retainer generates an excessive retentive force to cause the movement of abutment tooth, thereby resulting in the mobility of abutment tooth. Additionally, this increases the load of the abutment tooth, and eventually the abutment tooth is lost. Inadequate use of removable partial denture must be avoided as much as possible so as not to lose a natural tooth, an integral part of a human body. Regarding the measurement of the retentive force of the clasp for removable partial denture, there are also several studies on clasps using the finite element method [4], on measuring the retentive force using a universal testing machine with a crosshead speed [5], on measuring the retentive force with a fixed sensor [6], on cyclic fatigue properties of alloy cast clasps [7], on clasp evaluation of abutment tooth mobility [8], on the comparison of buccal and lingual retention [9], and on clasps compared with the metal materials used [10]. However, these are all research related to in vitro study, and until now there has been no device in the dental field that can easily measure the retentive force of clasp of removable partial denture in the oral cavity. There are no studies that measured the retentive force of a clasp of removable partial denture actually worn by patient. The study considers it very meaningful to present a retentive force measurement device that can be easily used in clinic to provide a removable partial denture with adequate retentive force.

The purpose of the present study is to develop a small-sized retentive force measurement device that can easily measure the retentive force of a clasp used for a removable partial denture in daily clinical practice, and it is to examine the inter-rater and intra-rater reliability.

Materials And Methods
Development of the small-sized retentive force measurement device
The small-sized retentive force measurement device has a structure that detects force as bending moment. Processing was carried out to the side where there was no chip at the tip of a commercially available band removing plier (band-removing pliers for molars 60–104, Task Co., Ltd., Tokyo, Japan).
Two strain gauges (gauge length of 1 mm and a base size of 1.4 × 2.8 mm) [Kyowa Electronic Instruments Co., Ltd., Tokyo, Japan] for transducers were provided inside and two were given to the outside and a cable with 1.7 caliber was welded from the terminal of the gauge towards the handles. Strain gauge have characteristics such as excellent repeatability and linearity, and it is possible to measure force, load, pressure, and displacement [11]. After the coating process, the device was covered with a silicon rubber. For improvement of reproducibility, four-active-gauge method (torsion strain measurement method) was adopted, strain gauge bridge was assembled at four places, and the difference of strain generated at the four places was output. We reduced the output error due to the difference in the loading point.

\[ \varepsilon = \sigma / E \text{ from } \sigma = \varepsilon E \]

By outputting the difference between strain detection positions L1 and L2, \( \varepsilon = F \cdot (L1 - L2) / (Z \cdot E) \) (\( \varepsilon \): strain output, \( \sigma \): stress, \( F \): force, \( Z \): section modulus, \( E \): Young's modulus, \( M \): bending moment, \( L \): distance)

Subtracting L2 from L1 is always invariable irrespective of the position of the load point, the structure was such that the magnitude of the load F can be accurately measured. For the sensor conditioner, the present study used a compact digital indicator (Kyowa Electronic Instruments Co., Ltd. WDS-190AS1, Tokyo, Japan) to quantify the retentive force of various clasps. The amount of distortion at the time of measurement can be converted and displayed as retentive force. The output sensitivity was fixed at about 500 × 10⁻⁶ strain/1 kgf. The maximum peak value of the retentive force is presented on the display by applying the shorter side of the small-sized retentive force measurement device attached with strain gauges on the lower arm of the retention arm of the undercut area of the retainer affixed on the abutment tooth and by vertically applying the flat-tipped edge on the occlusal surface of the abutment tooth. Figure 1 shows the small-sized retentive force measurement device developed. Figure 2 shows the structural schematic diagram.

**Change To Device Calibration**

The strain level is measured using a measuring instrument (Kyowa Electronic Instruments Co., Ltd. PCD-300B, Tokyo, Japan) to measure the strain value of the plier gauge when each load is applied to
the strain sensing area of the plier of the small-sized retentive force measurement device. To confirm whether the measurement using the small-sized retentive force measurement device can be properly done, the strain levels (µε) were measured under the loads of 0 g, 100 g, 200 g, 400 g, 800 g, 1200 g, 1600 g, and 2000 g.

Production Of 10 Types Of Cast Clasps
The 10 types of cast clasps are as follows.

A RPI clasp and a combination clasp using 0.25 mm undercut, a hairpin clasp, a ring clasp, an Akers clasp, a half and half clasp, a reverse backaction clasp, a backaction clasp, a double Akers clasp, and an extended arm clasp using the 0.50 mm undercut (Fig. 3).

Using commercially available hard plaster cast, a skilled dental technician has made 10 types of cast clasps used in clinical practice using conventional techniques. Regarding production of 10 types of cast clasps, a pre-made wax pattern for cast clasp (wax pattern MK 110-002-00, Dentaurum Co., Ltd., Osaka, Japan) was used for cast clasp with undercut depth at 0.5 mm. It has been reported that the retentive force varies depending on the difference in modulus of elasticity of metal used for clasp [12]. A dental casting gold and silver palladium alloy (Kimpara G12, Ishihuku Metal Industry Co., Ltd., Tokyo, Japan) commonly used in dental practice in Japan was employed. Confirmation of conformity state of cast clasp was carried out using high spot indicator (Arti-Spot®, Bausch Occlusion Paper Japan, Osaka, Japan).

Retentive force measurement with the small-sized retentive force measurement device

There were 3 assessors who measured the retentive force of 10 types of cast clasps and had more than 5 years of clinical experience.

When the handle of the measurement device is closed so that the crosshead speed becomes constant, the retention arm slightly lift-up and the separation force generated at that time is measured. Figure 4 shows the measurement situation of the small-sized retentive force measurement device.

Statistical analysis
In order to confirm whether there was a difference in the retentive force of the same as cast clasp,
the statistical analysis was performed by Friedman rank test for the measurement values of the assessor 3 times. In order to confirm the reliability within the assessor, the intra-class correlation coefficients ICC (1,1) and ICC (1,3) of the 3 assessors were calculated, and the reliability within the assessor was examined. Further, in order to confirm the reliability between the assessors, the inter-class correlation coefficients ICC (3,1) and ICC (3, 3) were calculated from the average of the measured values of the 3 assessors, and the reliability between the assessors was examined.

Analytical software PASW Statistics 18 (SPSS, IBM Co., Tokyo, Japan) was used for statistical analysis. The level of significance was set at 1%.

Results

Relationship between load and strain amount by the small-sized retentive force measurement device

The strain levels (µε) measured by the small-sized retentive force measurement device when the loads of 0 g, 100 g, 200 g, 400 g, 800 g, 1200 g, 1600 g, and 2000 g were respectively added showed a straight-line increase, which can be translated into a linear function (calibration constant: 0.4610 g/1 µε) (Fig. 5).

Retentive force measurement using the small-sized retentive force measurement device

Table 1 shows the results of retentive force measurement of 10 types of cast clasps. As for the measurement values of 3 assessors, as a result of Friedman rank test, no significant difference was found in the measurement values of assessors 1, 2, and 3 (P = 1.34, P = 0.99, P = 0.55). The intra-class correlation coefficients of 3 assessors are as follows: assessor 1 has ICC (1,1) = 0.971, ICC (1,3) = 0.990, assessor 2 has ICC (1,1) = 0.967, ICC (1,3) = 0.989, and assessor 3 has ICC (1,1) = 0.962, ICC (1,3) = 0.987. From the evaluation standard of the intra-class correlation coefficients of reliability value by ICC [13], it was evaluated as almost perfect and high reproducibility was confirmed. In order to confirm the reliability between 3 assessors, the intra-class correlation coefficients calculated from the average value of the measured values of the 3 assessors was ICC (3,1) = 0.993, ICC (3,3) = 0.998. From the evaluation standard of the intra-class correlation coefficients of reliability values by ICC [13], it was evaluated as almost perfect and it was found that the reliability between assessors was high.

Discussion

In principle, the effect of support and bracing works when wearing a partial denture, and the effect of
retention does not act during wearing of a partial denture because the retentive force acts on the sustaining arm that has entered the undercut when detaching the partial denture. When wearing a partial denture, the clasp closely conforms to the tooth surface and should not exert any force on the tooth. No burden on the abutment tooth is observed and prevents detachment of the denture. The retentive force of a clasp works only when the denture is removed. To date, retentive force of a clasp has been reported in many laboratory studies [6, 14-18].

Ahmad et al. [14] mentioned that the mean retentive force for a framework engaging an undercut of 0.25 mm with Akers clasp was 4.77 N. Nagasawa et al. [15] reported that an adequate amount of retentive force of a denture is around 500–1000 g per abutment tooth, while Okawa [16] speculates the retentive force per tooth between 500 g and 1000 g to be adequate. Tobita et al. [17] examined the basic shape of double-armed clasps with a rest made of Au-Pd alloy by conducting a tension test using a force meter. The result showed the force on the lower second premolar at 704 ± 7.5 g with the undercut depth at 0.5 mm, while the force on the lower second molar was at 775 ± 7.5 g. Hachikawa et al. [6] measured the retentive force rendered on the abutment tooth at the detachment of clasps on a plaster cast via the contactless sensors. The result found the force at 330 g with the double-armed clasp with a rest and cast guiding planes, 675 g with a double-armed clasp with a rest and without cast guiding planes, 785 g with a 0.9 mm double-armed clasp with a rest and without bent-wire guiding planes, and 360 g with an RPI clasp. Edward et al. [18] found that retentive forces of Co-Cr clasps at undercut depths of 0.25 mm, 0.50 mm, and 0.75 mm were 2.34 ± 0.23 N, 4.65 ± 0.35 N, and 7.56 ± 0.50 N, respectively. These numerical data are similar to the measurements of retentive force of the clasp of the present study using the small-sized retentive force measurement device.

In the present study, no significant difference was found in the measured values of the assessors 1, 2, and 3, indicating that the measurement results of this device are reproducible. Intraclass correlation coefficients are used in reliability studies [13, 19-21]. In the present study, intraclass correlation coefficients was used to examine whether there was inter-rater reliability and intra-rater reliability when measuring the retentive force of 10 types of cast clasps. The standard of intraclass correlation coefficients is 0.0 to 0.20 for slight, 0.21 to 0.40 for fair 0.41 to 0.60 for moderate, 0.61 to 0.80 for
substantial, 0.81 to 1.00 for almost perfect [13]. ICC (1,1) indicates the intra-rater reliability when one evaluator makes multiple evaluations. ICC (1,3) indicates the reliability of the average value when one evaluator makes multiple evaluations. As a result of the present study, ICC (1,1) and ICC (1,3) of 3 assessors showed 0.9 or more. Accordingly, it was confirmed that the reproducibility within the assessor of this measurement device was high. ICC (3,1) indicates the inter-rater reliability when multiple evaluators evaluate once. ICC (3,3) indicates the reliability of the evaluation average value when multiple evaluators evaluate once. As a result of the present study, ICC (3,1) and ICC (3,3) of 3 assessors were both 0.9 or more, and it was found that the reliability between assessors was high. Thus, it was confirmed that the retentive force measurement by the developed small-sized retentive force measurement device has high reliability within and between the assessors. By using the small-sized retentive force measurement device, it is possible to observe the retentive force of the removable partial denture actually worn by the patient. Based on objective values, it is considered that regular management of partial dentures will be possible.

Conclusions
The present study successfully developed a small-sized retentive force measurement device that enables an easy, chairside measurement of the retentive force of various clasps applied to removable partial dentures. From examining the intraclass correlation coefficients, it was confirmed that the developed small-sized retentive force measurement device has reproducibility within and between the assessors.

Declarations

Acknowledgments
The present study was supported by Grant-in-Aid for Scientific Research (C) 15K11176 from the Japan Society for the Promotion of Science, Tokyo, Japan and Project Research 2018 of Nippon Dental University, School of Life Dentistry.

Compliance with ethical standards

Conflict of interest
The author reports no conflicts of interest related to the present study.
Ethical approval

This article does not contain any studies with human participants or animal performed by any of the authors.

References

1. Kratochvil FJ. Partial removable prosthodontics. 1st ed. WB. Saunders Co;1988.
2. Renner RP, Boucher LJ. Removable partial dentures. Chicago: Quintessence Pub. Co.; 1987.
3. Reddy JC, Chintapatla SB, Srikakula NK, Juturu RK, Paidi SK, Tedlapu SK, Mannava P, Khatoon R. Comparison of retention of clasps made of different materials using three-dimensional finite element analysis. J Clin Diagn Res. 2016;10:ZC13-6.
4. Yuasa Y, Sato Y, Okawa S, Nagasawa T, Tsuru H. Finite element analysis between clasp dimension and flexibility. J Dent Res. 1990;69:1664-68.
5. Kim D, Park C, Yi Y, Cho L. Comparison of cast Ti-Ni alloy clasp retention with conventional removable partial denture clasps. J Prosthet Dent. 2004;91:374-82.
6. Hachikawa M, Igarashi Y, Shiba A. Stress analysis of abutment teeth on removal of RPDs, Part1. J Showa Univ Dent Soc. 1987;7:104-14.
7. Cheng H, Xu M, Zhang H, Wu W, Zheng M, Li X. Cyclic fatigue properties of cobalt-chromium alloy clasps for partial removable dental prostheses. J Prosthet Dent. 2010;104:389-96.
8. Igarashi Y. Selection of retainers in lower overlay denture-in relation to the abutment tooth mobility. Bull Tokyo Med Dent Univ. 1975;22:207-20.
9. Firtell DN, Grisius RJ. Retention of obturator-removable partial dentures a comparison of buccal and lingual retention. J Prosthet Dent. 1980;43:212-17.
10. Bridgeman JT, Marker VA, Hummel SK, Benson BW, Pace LL. Comparison of titanium and cobalt-chromium removable partial denture clasps. J Prosthet Dent. 1997;78:187-
11. Kumagai T. Strain Gauge and Bridge Circuits. Journal of SICE. 2006;45:323-28.
12. Bates JF. The mechanical properties of the cobalt-chromium alloys and their relation to partial denture design. Brit Dent J. 1965;119:389-96.
13. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:159-74.
14. Ahmad I, Sherriff M, Waters NE. The effect of reducing the number of clasps on removable partial denture retention. J Prosthodont Dent. 1992;68:928-33.
15. Nagasawa T, Kubo M, Maeno N, Yamashina T, Tsuru H. Experimental study on the decrease of retentive force of several attachments. J Hiroshima Univ Dent. 1978;10:63-9.
16. Okawa S. Experimental studies on retentive force of telescope crowns. J Hiroshima Univ Dent. 1986;18:166-80.
17. Tobita S, Kohno S, Watanabe K, Okada N. Study on clasp shapes and retentive force of Akers clasp in Ag-Pd-Cu-Au alloys. Niigata Dent J. 2003;33:45-51.
18. Edward TP, Leo YY, Henry WK, Fredrick CS, John C, Tak WC. Comparison of the retentive characteristics of cobalt-chromium and commercially pure titanium clasps using a novel method. Int J Prosthodont. 2006;19:371-72.
19. Bartko JJ. The intraclass correlation coefficient as a measure of reliability. Psychological Reports. 1966;19:3-11.
20. Shrout PE, Fleiss JL. Intraclass correlations uses in assessing rater-reliability. Psychol Bull. 1979;86:420-28.
21. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropractic Med. 2016;15:155-63.

Tables
Table 1 The results of retentive force measurement of 10 types of cast clasps

| 10 types of cast clasps | Model number (Nissin Co.,Ltd) | Undercut amount | Assessor 1 | Assessor 2 | Assessor 3 |
|------------------------|-------------------------------|-----------------|-----------|-----------|-----------|
|                        |                               | 1st time(g) | 2nd time(g) | 3rd time(g) | 1st time(g) | 2nd time(g) | 3rd time(g) | 1st time(g) | 2nd time(g) | 3rd time(g) |
| RH clasp               | E3-322                        | 0.25mm         | 262.4     | 218.5     | 239.3     | 197.3     | 282.6     | 230.8     | 273.7     | 230.6     | 245.2     |
| Combination wire clasp | E3-383                        | 0.25mm         | 291.4     | 235.6     | 310.2     | 256.9     | 270.6     | 217.8     | 334.3     | 295.2     | 265.3     |
| Hairpin clasp          | E3-545                        | 0.5mm          | 530.7     | 513.4     | 464.5     | 517.4     | 542.1     | 616.4     | 584.2     | 489.3     | 510.7     |
| Ring clasp             | E3-334                        | 0.5mm          | 632.4     | 643.3     | 680.4     | 664.6     | 632.5     | 685.3     | 632.2     | 659.2     | 599.2     |
| Akers clasp            | E3-541                        | 0.5mm          | 737.4     | 659.5     | 630.5     | 690.4     | 630.2     | 604.7     | 679.3     | 690.6     | 722.4     |
| Half and half clasp    | E3-563                        | 0.5mm          | 752.3     | 680.5     | 690.8     | 732.3     | 680.4     | 673.2     | 610.2     | 732.3     | 677.3     |
| Reverse backaction clasp | E3-522                     | 0.5mm          | 730.5     | 740.5     | 710.3     | 650.3     | 708.5     | 743.2     | 688.4     | 751.3     | 707.3     |
| Backaction clasp       | E3-567                        | 0.5mm          | 670.3     | 732.7     | 765.4     | 703.5     | 763.2     | 740.2     | 747.3     | 688.6     | 770.2     |
| Double Akers clasp     | E3-530                        | 0.5mm          | 898.2     | 810.4     | 880.6     | 840.2     | 862.5     | 780.3     | 821.3     | 879.3     | 760.1     |
| Extended arm clasp     | E3-546                        | 0.5mm          | 929.3     | 870.4     | 860.4     | 880.2     | 924.4     | 826.3     | 951.3     | 889.3     | 834.2     |

Figures
The developed small-sized retentive force measurement device

![Image of the developed small-sized retentive force measurement device]

Figure 1

The structure schematic of the developed small-sized retentive force measurement device

![Structure schematic of the developed small-sized retentive force measurement device]

Figure 2
10 types of cast clasps used in the present study
Figure 4

The measurement situation of the small-sized retentive force measurement device
Figure 5

Relationship between load and strain amount by the small-sized retentive force measurement device.