J Med Dent Sci 2001; 48: 105–111

Original Article

Dynamic retentive force of a mandibular unilateral removable partial denture framework with a back-action clasp

Innim Park, DDS*, Miho Eto, DDS*, Noriyuki Wakabayashi, DDS, PhD, Masayuki Hideshima, DDS, PhD*** and Takashi Ohyama, DDS, PhD******

Removable Prosthodontics, Department of Masticatory Function Rehabilitation, Division of Oral Health Sciences, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan
(Graduate Student, Research Associate**, Assistant Professor***, Professor****)*

Part of this study was presented at the 104th meeting of the Japan Prosthodontic Society (Osaka, Japan, November 2000).

Purpose: The purpose of this study was to investigate the dynamic retentive force of a mandibular unilateral distal-extension partial denture framework with a back-action clasp that was designed in a buccally tilted cast on a dental surveyor. The retention mechanism of this framework was analyzed in comparison with other typical unilateral and bilateral frameworks for the mandibular Kennedy class II case.

Materials and Methods: Experimental gold alloy frameworks of three designs were repositioned to the master cast, and lifted upward to the vertical direction to the occlusal plane. The load required to dislodge each framework was recorded. The retentive force of each framework was determined by the maximum load in a dislodgment cycle. The bending strength of a plain clasp pattern of the same length as the clasp arm used in each framework was also measured by cantilever beam test.

Results: The mean retentive force of the unilateral framework with a back-action clasp of relatively low bending strength was significantly higher ($P < 0.01$) than that of the unilateral framework with two Akers clasps of relatively high bending strength, and 70 to 80% of the bilateral framework with two Akers clasps on the edentulous side and a double Akers clasp on the contralateral side. The unilateral framework with a back-action clasp showed the greatest early load resistance in the dislodgment cycle among the three designs.

Conclusion: The reasonable retention mechanism was demonstrated by the unilateral framework with a back-action clasp.

Key words: retentive force, removable partial denture, back-action clasp

Introduction

In a distal-extension removable partial denture (RPD) for a unilateral edentulous area, the retention and stability of the denture are usually gained by an indirect retainer placed in the contralateral side of the arch to the saddle. The indirect retainer in a form such as a double Akers clasp, connected by a major connector to the denture saddle, is expected to stabilize the saddle by the cross-arch bracing[1,2].

Correspondence to: Dr. Innim Park
Removable Prosthodontics, Department of Masticatory Function Rehabilitation, Division of Oral Health Sciences, Graduate School, Tokyo Medical and Dental University, 1-5-45, Yushima 1-chome, Bunkyo-ku, Tokyo 113-8549, Japan
Fax: Int.81-3-5803-0200
E-mail: park.rpro@ tmd.ac.jp
Received May 9; Accepted September 25, 2001

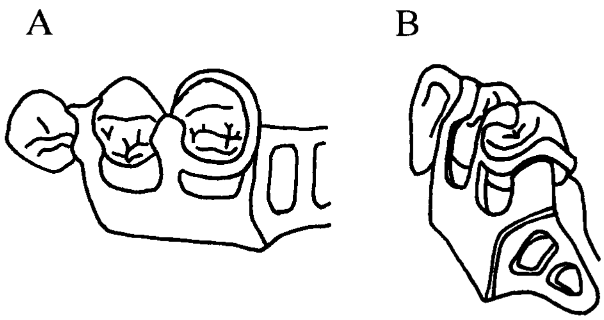

Fig. 1. Schematic illustrations of the unilateral denture framework with a back-action clasp. A, an occlusal view; B, a linguo-distal view. Notice that the back-action clasp arm and the proximal plate placed on the distal surface of the right second premolar is separated by a minute slit.

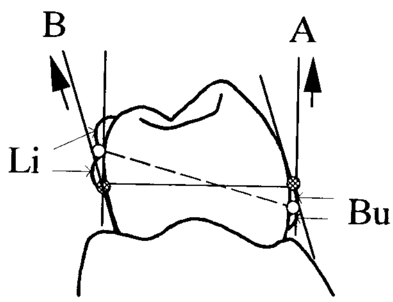

Fig. 2. A frontal view of the back-action clasp arm on the mandibular second premolar. A, perpendicular direction to the occlusal plane; B, the modified direction of placement by tilting the cast buccally on surveying; Bu, buccal arms; Li, lingual arms. The dotted line shows a survey line before tilting the cast, and the solid line represents a survey line after tilting the cast.

Unilateral distal-extension RPDs have not been broadly used because of their potential problems of lack of retention[3] and stability that may cause vertical and horizontal hazardous denture displacement in function[4]. The lack of stability may allow excessive stresses on residual ridge and abutment teeth, resulting in tissue absorption and eventual loss of the teeth[5]. The major connectors and multiple retainers usually incorporated in the bilateral RPDs, however, can be obstructive to the patients. Patients wearing unilateral RPDs are likely to feel comfortable due to their simplicity during speech, swallowing, or mastication.

In the partially edentulous case with missing unilateral first and second molars, we have proposed a unilateral distal-extension RPD design that features a back-action clasp as a direct retainer, and an embrasure hook engaged in anterior abutment of the edentulous side as an indirect retainer **(Fig. 1)**. To overcome the difficulty in gaining retention and stability of the unilateral denture, the path of denture placement is intentionally determined by tilting the cast buccally on surveying, as shown in **Fig. 2**. Consequently, the lingual arm of the clasp and a part of the minor connector on the lingual surface of the abutments are located in the undercut area to the vertical direction to the occlusal plane. It is expected that vertical dislodgment of the denture is strongly resisted in function by those rigid parts of the framework.

The purpose of this study was to investigate the dynamic retentive force of the mandibular unilateral partial denture framework with a back-action clasp, and analyze the retention mechanism of this framework in comparison with other typical unilateral and bilateral frameworks for a Kennedy class II partially edentulous case.

Materials and Methods

Experimental denture frameworks

A mandibular dentate plaster model (E 50-518, Nissin Dental Products Inc., Kyoto, Japan), with a posterior edentulous area due to missing right first and second molars, was used as the master cast in the experiment. The abutment teeth of the plaster model; the right canine, and the bilateral first and second premolars, were replaced with gold alloy (PGA-2, Ishifuku Metal Industry Co., Tokyo, Japan) casting teeth to avoid surface wear and breakage during the testings.

Schematic designs of three framework designs are illustrated in **Fig. 3**. Framework A employed a unilateral design with a single back-action clasp as a direct retainer on the second right premolar. The design concept of this framework was described in the introduction. The path of denture placement was determined on the dental surveyor by tilting the cast 10 degrees buccally to the perpendicular direction to the occlusal plane. Frameworks B and C were designed on teeth relative to the horizontal survey. Framework B featured two Akers clasps on the right first and second premolars. Framework C featured the cross-arch design with a lingual bar, two Akers clasps on the right premolars, and a double Akers clasp on the left premolars as an indirect retainer. Both the buccal and the lingual tips of the Akers clasps engaged 0.2 mm undercut area while that of the back-action clasp engaged an undercut of 0.25 mm. The back-action clasp arm was approximately 22 mm long, while the buccal and lingual arms of Akers clasps were 13 mm and 10 mm, respectively. Each clasp arm was formed by means of a preformed wax pattern (Bego, Bremen, Germany), and cast in the same gold alloy as used for the abutment teeth. Three experimental frameworks were prepared each for the three framework designs. Each framework incorporated a metal plate at the saddle skeleton standing perpendicular to the occlusal plane for retention of tensile rod.

Retentive force of the frameworks

Each framework was repositioned to the master cast fixed on the experimental stage in the universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan). For the first series of experiments (grip test), the metal plate with retention holes in each framework was temporarily attached to a tensile rod connected to the testing machine by means of an autopolymerizing resin (Unifast Trad, GC, Tokyo, Japan). Schematic illustrations of the testing device are shown in **Fig. 4**. Each framework was then subjected to tensile loading and lifted upward perpendicularly to the occlusal plane at a cross-head loading speed of 5 mm per minute. For the second series of experiments (suspension test), each framework was hanged and lifted from the testing machine by means of a S-shaped metal hook, then subjected to tensile loading at the same loading speed as for the grip test. The load required to dislodge each framework as a function of vertical displacement was recorded. The retentive force of each framework was determined as the maximum load in a dislodgment cycle. The test was repeated five times for each experimental framework. One-way analysis of variance (ANOVA) and Scheffe's post-hoc test (Statview 4.5, Abacus Concepts Inc., USA) were performed to determine significant differences in the retentive forces among the framework designs ($P < 0.01$). The dislodgment tests were monitored by means of a digital video camera (DCR-TRV 900, Sony, Tokyo, Japan) for confirmation and analysis of the dislodgment pathways of the frameworks.

Bending strength of the clasp beams

The bending strength of a plain clasp pattern beam (Bego, Bremen, Germany) with the same length as each clasp arm used in the experimental frameworks was measured by cantilever beam test to provide reference data for the retention test. Each plain clasp beam was clamped at the neck of the clasp, and loaded at the clasp tip from the inner surface to the outer surface of the clasp perpendicularly to the beam direction until the beam deflected the length corresponding to the amount of undercut used in the

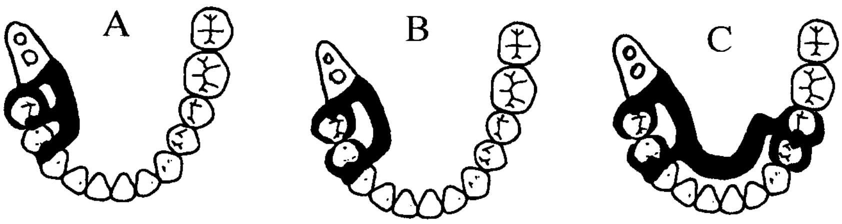

Fig. 3. Experimental framework designs used in the study.

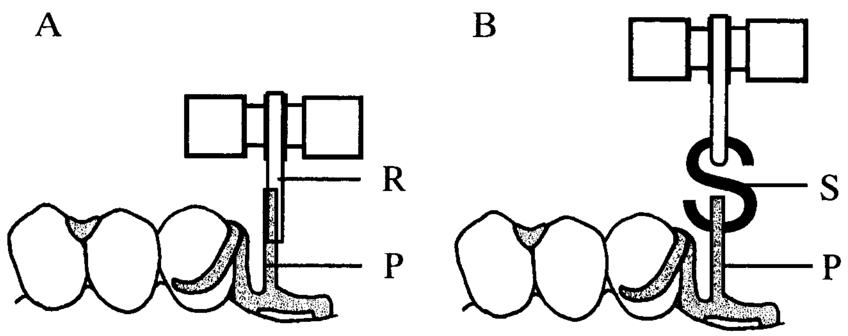

Fig. 4. Schematic illustrations of the dislodgment test. A, grip test; B, suspension test; P, retention plate in the framework saddle; R, tensile rod connected to the universal testing machine; and S, S-shaped metal hook.

experimental framework. The bending strength was then recorded three times for each clasp beam, and the average value was used as the bending strength of the clasp beam.

Results

Fig. 5 shows load-vertical displacement curves of representative frameworks each from three design groups in the grip test. The means and standard deviations of the retentive forces for the three design groups in the grip test are summarized in **Fig. 6**. The mean retentive force of framework C (25.6 N) was the highest, followed by frameworks A (20.0 N) and B (16.1 N). There were significant differences between any two experimental groups in the three groups ($P < 0.01$). In the load-vertical dislodgment curves (Fig 5), framework A demonstrated the greatest inclination (increase rate) in its early stage of dislodgment (39.0 N/mm), followed by frameworks C (33.2 N/mm) and B (20.8 N/mm).

Fig. 7 shows load-vertical displacement curves of representative frameworks each from three design groups in the suspension test. For framework C, there were two peaks in the load-vertical displacement curve; the first peak obviously represented the dislodgment of the direct retainer, and the second peak coincided with the dislodgment of the indirect retainer on contralateral side of the arch. The maximum load resistance (retentive force) was recorded consistently at the first peak of the curve. The means and standard deviations of the retentive forces for the three design groups in the suspension test are summarized in **Fig. 8**. Framework C revealed the highest mean retentive force (10.0 N), followed by frameworks A (6.9 N) and B (4.6 N). There were significant differences between any two experimental groups in the three groups ($P < 0.01$). The retentive forces in the suspension test were approximately 30～40% of those in the suspension test. In the load-vertical displacement curves (Fig 7), framework A demonstrated the greatest inclination (increase rate) in its early stage of dislodgment (10.6 N/mm), followed by frameworks C (8.0 N/mm) and B (7.0 N/mm).

Table 1 shows the means and standard deviations of the bending strengths of the plain clasp beams by the cantilever beam test. The mean bending strength of the back-action clasp beam with corresponding length to the clasp arm in framework A, was less than 1 N when the tip of the clasp deflected 0.25 mm (the amount of undercut). The buccal and lingual arms of clasp beams that corresponded to the clasps in the frameworks B and C, demonstrated bending strengths of between 2 N and 5 N. As the length of a clasp arm increased, the strength required to deflect the clasp clearly decreased.

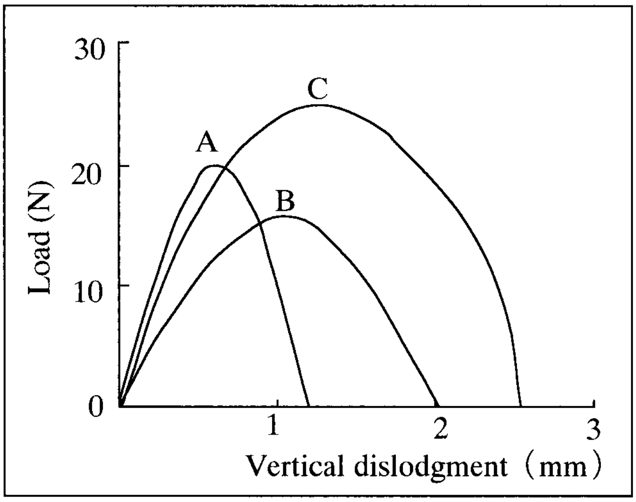

Fig. 5. Load-vertical displacement curves of representative frameworks each from the three designs (A, B, and C) in the grip test.

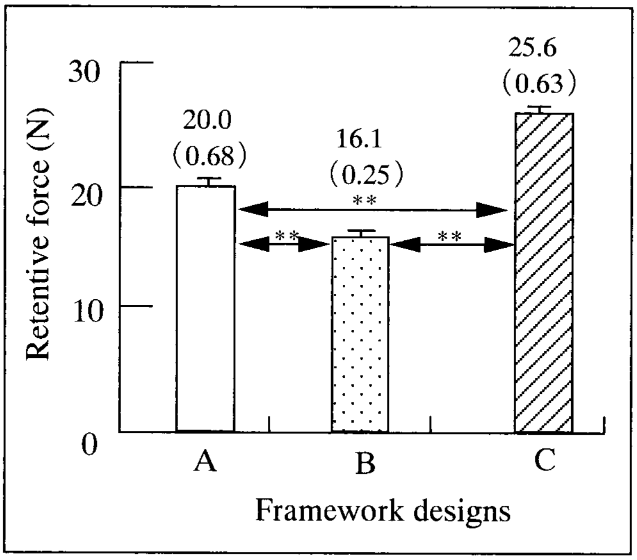

Fig. 6. The means and standard deviations of the retentive forces for the three designs in the grip test.

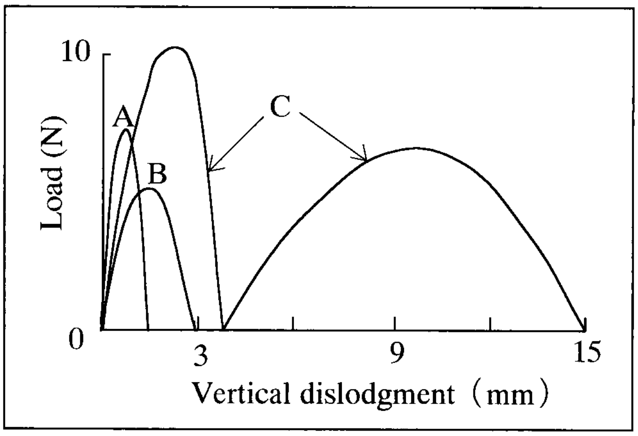

Fig. 7. Load-vertical displacement curves of representative frameworks each from the three designs (A, B, and C) in the suspension test.

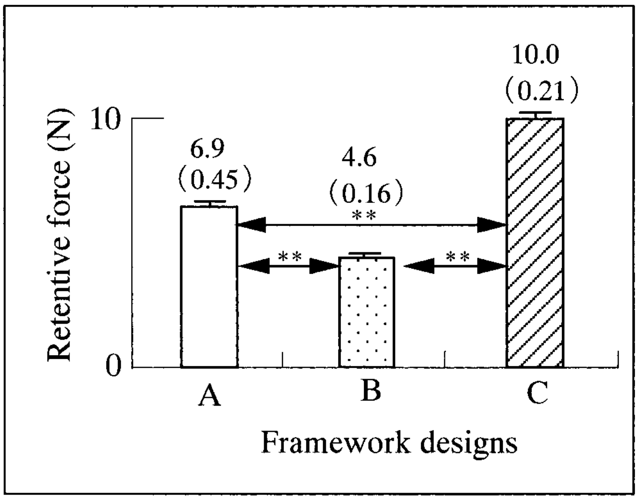

Fig. 8. The means and standard deviations of the retentive forces for the three designs in the suspension test.

Table 1. The mean bending strengths of the plain clasp arm beams by cantilever beam test

	Designs	A	B		C			
	Abutment teeth	5┐	5┐	4┐	5┐	4┐	┌4	┌5
Buccal arm	Length (mm)	22	13	12	13	12	12	13
	Strength (N)	0.8	1.7	2.1	1.7	2.1	2.1	1.7
	(S.D.)	(0.2)	(0.15)	(0.07)	(0.15)	(0.07)	(0.07)	(0.15)
Lingual arm	Length (mm)		10	9	10	9	9	11
	Strength (N)		3.3	5.4	3.3	5.4	5.4	2.8
	(S.D.)		(0.16)	(0.28)	(0.16)	(0.28)	(0.28)	(0.05)

*The amount of deflection (undercut); clasp arm in framework A, 0.25 mm; clasp arms in frameworks B and C, 0.2 mm.

Discussion

Although cobalt-chromium alloy has been the most popular partial denture alloy because of its low cost and rigidity, the gold alloy used in the experimental frameworks may be suitable for clasps because of its high flexibility, high yield strength, and relatively low modulus of elasticity[6]. In addition to these clinical advantages, the excellent castability[7] and fatigue resistance[8] of the gold alloy were another reasons of using this alloy in the experimental frameworks.

The grip tests were conducted so that the direction path of dislodgment was regulated by fixing the framework to the tensile rod. The experimental condition in the grip test might not reproduce the denture dislodgment or removal in a real clinical situation, but it was likely to express the total amount of bending strengths of the clasps incorporated in each framework. The retentive forces demonstrated in each framework design in the grip test were much higher than those supposed to be sufficient for ordinary clinical requirements[9]. The experimental condition in the suspension tests, on the other hand, might be closer to clinical situations than that on the grip test, because it allows horizontal or rotational denture displacement during testing. The mean retentive forces in the suspension test (4 to 10 N) were approximately 30~40% of those in the grip test, but they were still considered enough for ordinary clinical requirements[9].

Framework C revealed the highest mean retentive force among the three designs in both grip and suspension tests, probably because it had more buccal and lingual retentive clasp arms with relatively high bending strengths. Despite the fact that framework A contained only a single back-action clasp of relatively low bending strength while frameworks B and C included multiple buccal and lingual clasps of high bending strengths, the mean retentive force of framework A was significantly higher than that of framework B, and between 70 % and 80 % of that of framework C in both grip and suspension tests. The results may be attributed to a unique retention mechanism generated in framework A. **Fig. 9(a)** captured an experimental view of a framework A in its early dislodgment stage in the suspension test before the load reached the peak (retentive force), and **Fig. 9(b)** demonstrated another view of the same framework immediately after the peak load was recorded in the same experimental sequence as shown in Fig 9(a). The buccal arm of the back-action clasp was lifted off at first, then the total part of the framework was dislodged in the late stage of the sequence. It was clearly shown in the suspension test that framework A was dislodged from the master cast with a lingually rotational movement as schematically illustrated in **Fig. 10**. This rotational movement might occur due to the frictional resistance generated by the rigid lingual bracing arm of the back-action clasp and a part of the minor connector located in a sufficient undercut area perpendicular to the occlusal plane. The retention mechanism demonstrated in framework A was quite different from other frameworks that obtained the most of their retention from the bending strengths of retentive clasp arms. This retention mechanism shown in framework A may also reasonably explain the greatest inclination value (increase rate) in its early stage of the load-vertical displacement curve among the three framework designs.

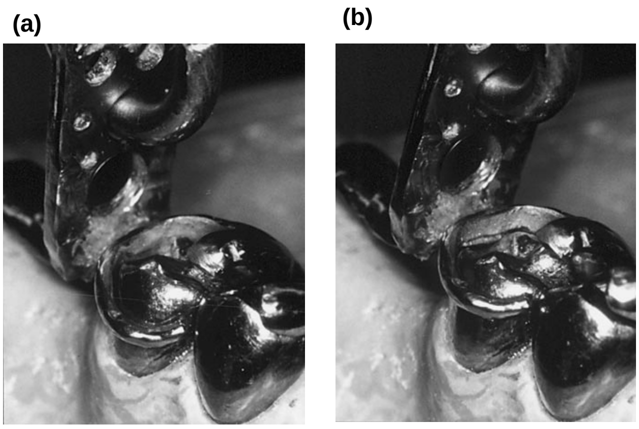

Fig. 9. (a) An experimental view from a motion picture of a framework A in its early dislodgment stage in the suspension test before the load (retentive force) reached the peak. (b) Another view of the same framework immediately after the peak load was recorded. Note that the framework with the retention plate lingually rotated.

Mandibular premolars that are usually used as abutments for direct and indirect retainers of distal-extension RPDs occasionally tilt lingually to the vertical direction to the occlusal plane, resulting in a relatively high survey line on the lingual surface of the abutment[10]. The lingual reciprocal arm of a circumferential clasp is required to be engaged at the corresponding height to the buccal arm to avoid a tilting effect of the clasp to the abutment during placement and removal of the denture. By tilting the cast buccally on surveying, the survey line on the lingual surface of the abutment is lowered, while that on the buccal surface is raised. Consequently, the lingual arm of the clasp in a lowered position may promise a reasonable reciprocal effect of the buccal arm, and may also generate the strong retention and stability to the denture[11].

The framework design featured in this study may be placed in an alternative category of the rotational path RPDs that have been described by King[12], Krol[13], and Jacobson[14]. The rotational path RPDs incorporate a curved or arcuate path of placement, allowing one or more of the rigid components of the framework to gain access to and engage an undercut area. The framework in this study is designed to be inserted on the linguo-buccal rotational axis, while the conventional rotational path framework is inserted on the mesio-distal rotational axis. In both design methodologies, the rigid part of the frameworks play an important role to

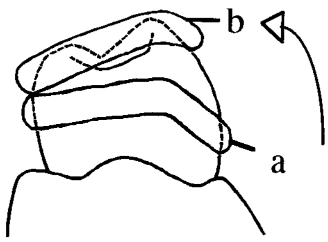

Fig. 10. The back-action clasp arm of framework A on the second premolar in a frontal view, before (a) and after (b) the peak load was recorded in the suspension test.

abridge some conventional retainers, and to enable gaining simplicity in the frameworks without compromising retention of the denture.

Acknowledgments

This study was financially supported by a Grant-in-Aid for Scientific Research (12771170 and 11671979) from the Ministry of Education, Science, Sports and Culture, Japan.

References

1. Walter JD. Removable partial denture design. London: British Dental Association, 1990:87-91.
2. Zarb GA, Bergman B, Clayton JA, MacKay HF (eds). Prosthodontic treatment for partially edentulous patients. St Louis: CV Mosby, 1978:415-436.
3. Lammie GA, Laird WRE. Osborne & Lammie's partial dentures, 5th ed. Oxford: Blackwell Scientific Publications, 1986:324-329.
4. Garver DG. A new clasping system for unilateral distal-extension removable partial dentures. J Prosthet Dent 1978;39:268-273.
5. Bates JF, Huggett R, Stafford GD. Removable denture construction, 3rd ed. London: Wright, 1991:61-64.
6. Cunningham DM. Comparison of base metal alloys and type IV gold alloys for removable partial denture frameworks. Dent Clin North Am 1973;17:719-722.
7. Pulskamp FE. A comparison of the casting accuracy of base metal and gold alloys. J Prosthet Dent 1979;41:272-276.
8. Vallittu PK, Kokkonen M. Deflection fatigue of cobalt-chromium, titanium, and gold alloy cast denture clasp. J Prosthet Dent 1995;74:412-419.
9. Frank RP, Nicholls JI. A study of the flexibility of wrought wire clasps. J Prosthet Dent 1981;45:259-267.
10. Fuller JL, Denehy GE. The permanent mandibular premolars. In: Hall SA (ed). Concise dental anatomy and morphology, 7th ed. Chicago: Year book medical publishers, 1984:116-134.
11. McGiveney GP, Castleberry DJ. McCracken's removable partial prosthodontics, 9th ed. St Louis: CV Mosby, 1995:94-100.
12. King GE. Dual-path design for removable partial dentures. J Prosthet Dent 1978;39:392-395.
13. Krol AJ, Finzen FC. Rotational path removable partial dentures, Part 1: Replacement of posterior teeth. Int J Prosthodont 1988;1:17-27.
14. Jacobson TE, Krol AJ. Rotational path removable partial denture design. J Prosthet Dent 1982;48:370-376.