Original Article

The effects of loading locations and direct retainers on the movements of the abutment tooth and denture base of removable partial dentures

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The purpose of this study was to evaluate the degree and amount of movement of the abutment tooth and denture base influenced by the direct retainer of distal extension removable partial denture and the location of functional loading, then to suggest direct retainer design with minimal adverse effect and with optimum functional loading location for residual tissue. The displacement of the abutment tooth and inclination of the denture base were determined, with 30 N as work load utilizing simulation model and strain guage system, about two types of direct retainers with mesial or distal rest and nine loading points on denture base. Displacement and inclination was determined with the one-way analysis of variance and Scheffe's multiple test was performed. The results revealed that type of direct retainer influenced on the magnitude rather than direction of the abutment tooth displacement. The distal displacement of abutment tooth was significantly less in Type M clasp (with mesial rest and connection) than in Type D clasp (with distal rest and connection) (p<0.05). The location of loading points influenced both of the magnitude and direction of the abutment tooth and denture base movement. Posterior and lingual loading resulted in signifi-cantly distal displacement of abutment tooth (p<0.05).

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Introduction

Removable partial dentures (RPD) for partially edentulous individuals is for restoration of oral function, preservation of remaining oral structures, and preven-tion of oral disease to the greatest extent possible. However, after treatment with the RPD, functional forces transmitted from the artificial teeth to the abut-ment teeth sometimes exceed the threshold of the physiological movements of the abutment teeth, then it is possible to speculate an increase in tooth mobility[1,2]. In other words, the differences in displaceability of the supporting abutment teeth and soft tissues covering the residual ridge permit rotational movement when the force is directed especially on the distal extension den-ture base, which results as a harmful stress on the abutment teeth and the residual ridge.

Several factors such as denture design (direct retainer[3-6] and indirect retainer[7]), fit of the denture base and framework[8], occlusal considerations[9] and morphology of residual ridges[10,11] are known to be relat-ed to the movement of the distal extension RPD. Especially, occlusal forces[12,13] which primarily cause denture movement result in the harmful movement of the abutment teeth through the occlusal rest of the direct retainer.

Periodontal Ligament Model
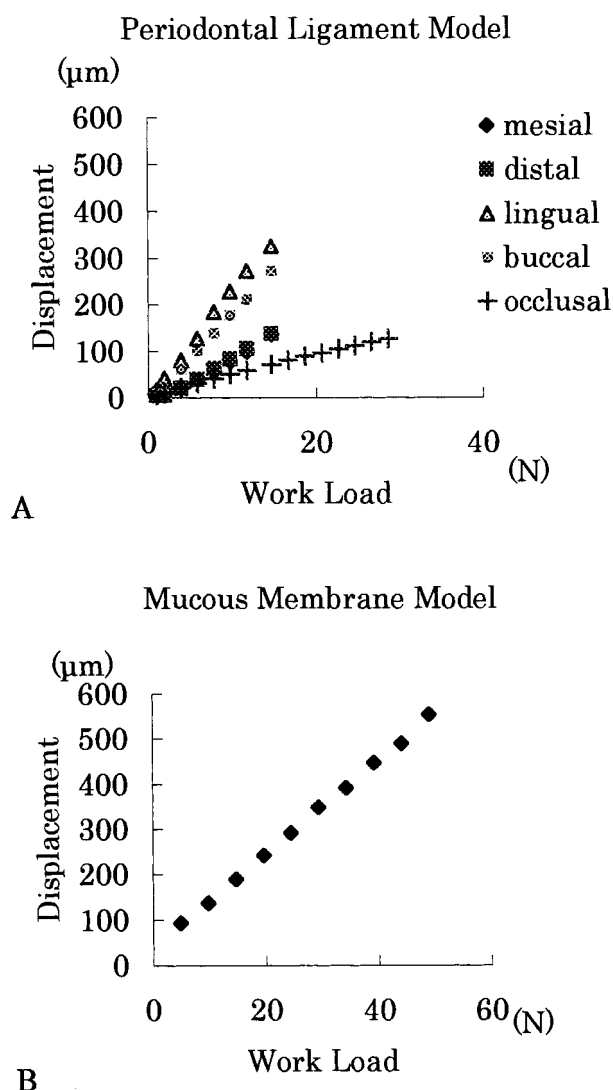

A

Mucous Membrane Model

B

Fig. 1. Displacement of simulated periodontal ligament and mucous membrane under work load. A: Periodontal ligament model. B: Mucous membrane model.

Therefore, it is important to clarify the influence of the movements of the denture bases and abutment teeth by means of loading points on the denture base and direct retainer designs, which will lead to the proper design of the RPD to prevent the harmful influences of torque[13] on the abutment tooth. Many studies have been conducted to clarify the movement of abutment tooth utilizing different types of direct retainers. Majority of the direct retainers comparatively analyzed in these studies had obviously different contact surface area of the tooth, and loading points were not fully considered in reference to occlusal conditions and arrangements of the artificial teeth.

The purpose of this study was to evaluate the degree and amount of abutment tooth and denture base mobility influenced by direct retainer utilizing of distal extension RPD and the points of functional loading, then to suggest a direct retainer design with minimal adverse effects and with optimum functional loading points for the residual tissue. In this study, the effects of two types of circumferential clasps and loading points on the abutment tooth and denture base movement were studied utilizing the simulation model of the mandibular unilateral distal extension RPD.

Methods and Materials

Experimental model

A plastic model (Devcon ET, I.T.W. Industries. Co., Japan) of the mandibular dental arch was constructed with edentulous spaces at the first and second molars to create a unilateral distal extension condition (Kennedy Class). The residual ridge was minimal loss of residual bone, in clinically good condition both of mesiodistally and buccolingually. The test model was fabricated with individual simulative materials for tooth structure, periodontal ligament, mucous membrane, and alveolar bone.

The premolars were cast in gold palladium alloy (Castwell M.C.12%Gold, GC.Co., Japan), and the primary abutment tooth had mesial and distal occlusal rest seats. The sockets for the premolars were enlarged, and silicone impression material (Exafine regular, GC.Co., Japan) with thickness of 1.0 mm was placed around the roots to simulate the periodontal ligament and to permit movement of the teeth. Approximately 4 mm of the cast was removed from the ridges to provide space for fabrication of a simulated mucous membrane. White silicone material (Fit checker, GC.Co., Japan) served in the simulation of the resilient mucous membrane. Displacements of simulated periodontal ligament and mucous membrane under pressure were shown in Fig.1A / B which indicated similarities between in vivo and in vitro displacement[14]. The contact space between the first and second premolars was adjusted to within 50 μm each other.

Experimental denture frame

Two cast circumferential direct retainers which were generally applied in clinical treatment were selected for evaluation. The first direct retainer (Type M, Back-action type) consisted of a mesial rest, a mesial minor connector, a mesiobuccal retentive arm and a lingual
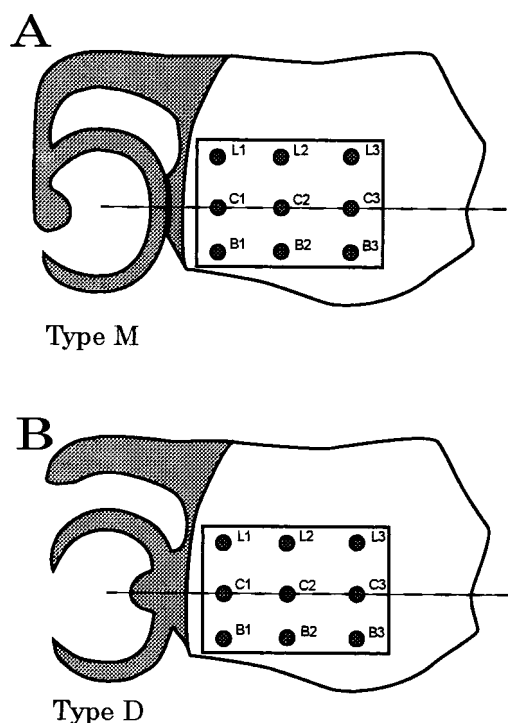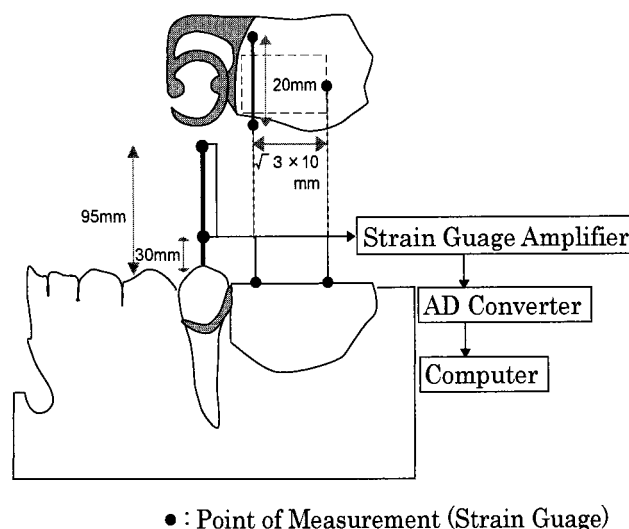
Fig. 2. Illustrated experimental denture with loading points. A: Type M clasp, B: Type D clasp. Major connector size (10× 5 mm, thickness 2 mm).

● : Point of Measurement (Strain Guage)

Fig. 3. Schematic block diagram of measurement.

bracing arm (Fig. 2A). The second (Type D, Akers type) had a distal rest, a distal minor connector, a mesiobuccal retentive arm and a lingual bracing arm (Fig. 2B). The shape and location of the retentive and bracing arm were the same in both types. The undercut engaged by the retentive arm was limited to 0.25 mm. The major connector of Type D was left in order to compare two types of direct retainers under the same condition as possible.

These frameworks cast in platinum gold alloy (Type , Ishifuku Metal Industry Co., Ltd., Japan) were fabricated by one dentist, and clasp wax pattern (No. 40021, BEGO. Co., Germany) was used to minimize variations of the shape. Four clasp assemblies were made for each of the two designs totaling of eight samples. The frameworks were physiologically adjusted for proper fit and for movement along the axis of rotation using the disclosing medium chloroform and rouge. The denture base was fabricated from auto-polymerizing resin (Mild Rebaron, GC.Co., Japan).

A cast loading platform simulating the occlusal plane was fabricated in gold palladium alloy, in which nine dimples for loading were constructed. The central loading points were determined mesiodistally at a dis-
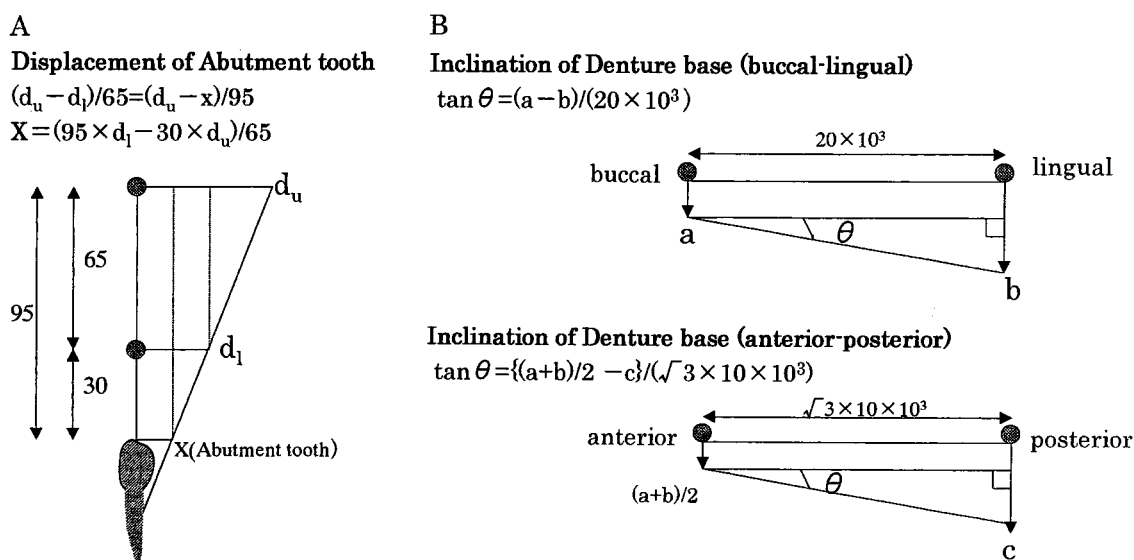
tance of 5 mm, 10 mm, 15 mm from the distal surface of second premolar to the center of retromolar pad (C1, C2 and C3, respectively), and buccolingual loading points were determined at a distance of 3 mm from the each central loading point (B1, B2, B3, L1, L2 and L3, respectively) (see Fig. 2).

Measurement

A constant loading of 30N was selected to refer the masticatory force and applied to the nine loading points with a custom-made portable loading machine. During loading, a stainless steel ball was placed on the dimple of the loading platform so that the loading will be perpendicular to the occlusal plane with uniformity. Each loading point was loaded and measured in an independent, random sequence for three seconds. The averaged value for two seconds immediately after loading was calculated. Five recordings were measured for each loading point.

Strain gauges were used to record the displacements of the abutment tooth and denture base during loading (Fig. 3). Its sensitivity was maintained at a constant by calibrating the machine resulting in maximum deviation of 10 μm. The displacements of the abutment tooth at the center of the occlusal surface in the mesiodistal and buccolingual directions and the denture base inclination in the anteroposterior and buccolingual direction were calculated (Fig. 4).

One-way analysis of variance (ANOVA) was used to test the differences among each group of direct retainers and for the variations in the loading points at each direct retainer. Values of $p < 0.05$ were considered

A

Displacement of Abutment tooth

$(d_u - d_l)/65 = (d_u - x)/95$

$X = (95 \times d_l - 30 \times d_u)/65$

B

Inclination of Denture base (buccal-lingual)

$\tan \theta = (a - b)/(20 \times 10^3)$

Inclination of Denture base (anterior-posterior)

$\tan \theta = \{(a+b)/2 - c\}/(\sqrt{3} \times 10 \times 10^3)$

Fig. 4. A: Displacement of abutment tooth (mesial-distal and buccal-lingual). The each value of mesial and buccal measurement points were measured using strain guages. d_u = displacement of upper measurement point. d_l = displacement of lower measurement point. X = displacement of abutment tooth. B: Inclination of denture base (anterior-posterior and buccal-lingual). The each value of buccal-anterior, lingual-anterior and posterior measurement points were measured using strain guages. a = displacement of buccal-anterior point of measurement on the denture base. b = displacement of lingual-anterior point of measurement on the denture base. c = displacement of posterior point of measurement on the denture base.

to be statistically significant, and Scheffe's multiple test was further performed for comparative analysis.

Results

Mesiodistal displacements of the abutment tooth were not significantly different between Type M and Type D under all buccal loadings (B1, B2 and B3), and the abutment tooth moved mesially (Fig. 5A). On the other hand, the abutment tooth moved distally under the central and lingual loadings (C1, C2, C3, L1, L2 and L3), and the abutment tooth of Type D moved significantly greater than that of Type M ($p < 0.05$) (Fig. 5A). Moreover, the posterior loading (C3) produced significantly greater abutment displacement than the anterior loading (C1) in both types ($p < 0.05$) (Fig. 6A). There were significant differences in the mesiodistal abutment displacements with buccolingual loadings ($p < 0.05$). That is, the abutment tooth moved mesially under the buccal loading, while it moved distally under the central and lingual loadings (Fig. 6A).

The buccolingual displacements of the abutment tooth were within 20 μm with no significant differences between Type M and Type D (Fig. 5B), anteroposterior loading points (Fig. 6B), and buccolingual loading points (Fig. 6B).

There were no significant differences in the anteroposterior inclination between Type M and Type D except for the buccal middle (B2) loading (Fig. 5C). On the other hand, both types of denture base significantly inclined posteriorly under the posterior loadings except for the lingual posterior (L3) loading of Type M ($p < 0.05$) (Fig. 6C).

The denture base of Type M inclined buccally greater than that of Type D under the buccal anterior (B1), buccal middle (B2), central anterior (C1), and central middle (C2) loadings ($p < 0.05$) (Fig. 5D). Denture base inclined buccally on the buccal loadings and lingually on the lingual loadings (Fig. 6D).

Although depression occurred at the denture base at majority loading points, the buccal side of Type M and Type D elevated under the lingual middle and posterior (L2 and L3) loadings and the lingual side of Type M elevated under the buccal anterior (B1) loading (Table).

Discussion

A lot of investigations[3,4,10,11,15-20] have been aimed at determining which design is most suitable for a direct retainer on the abutment tooth for the distal extension
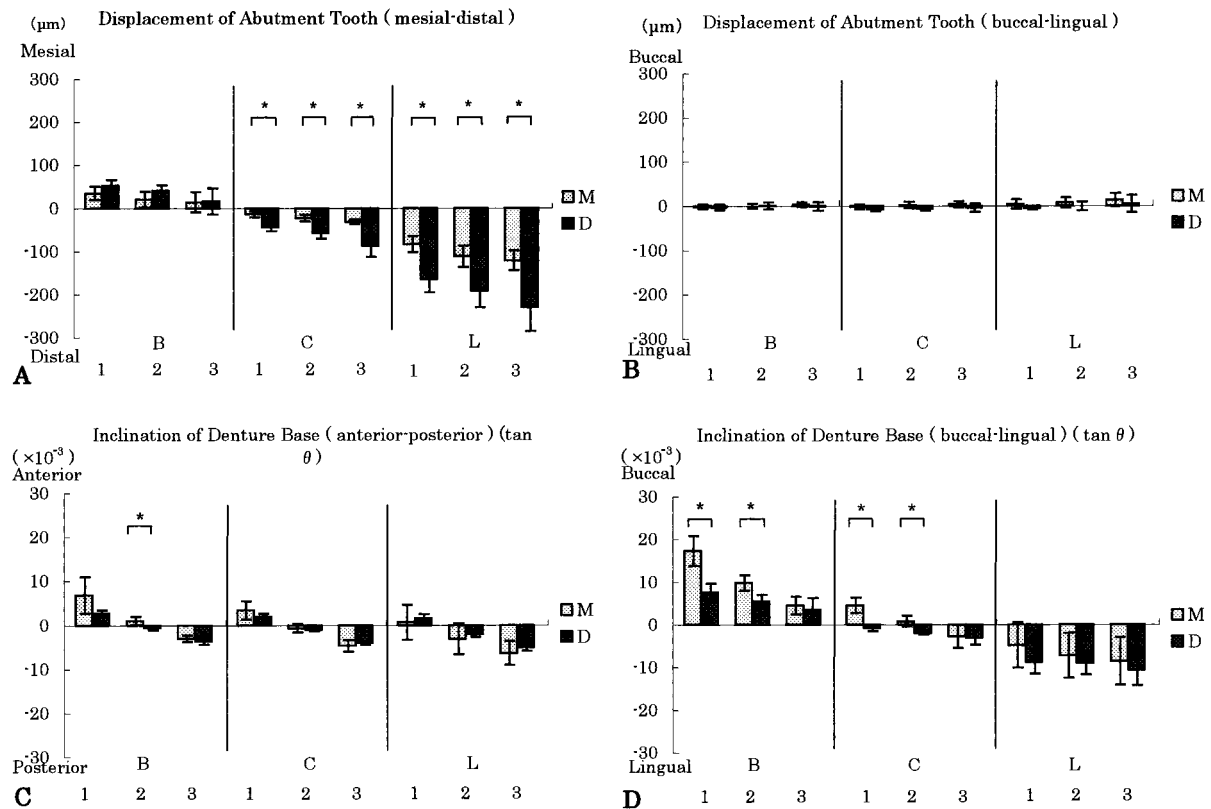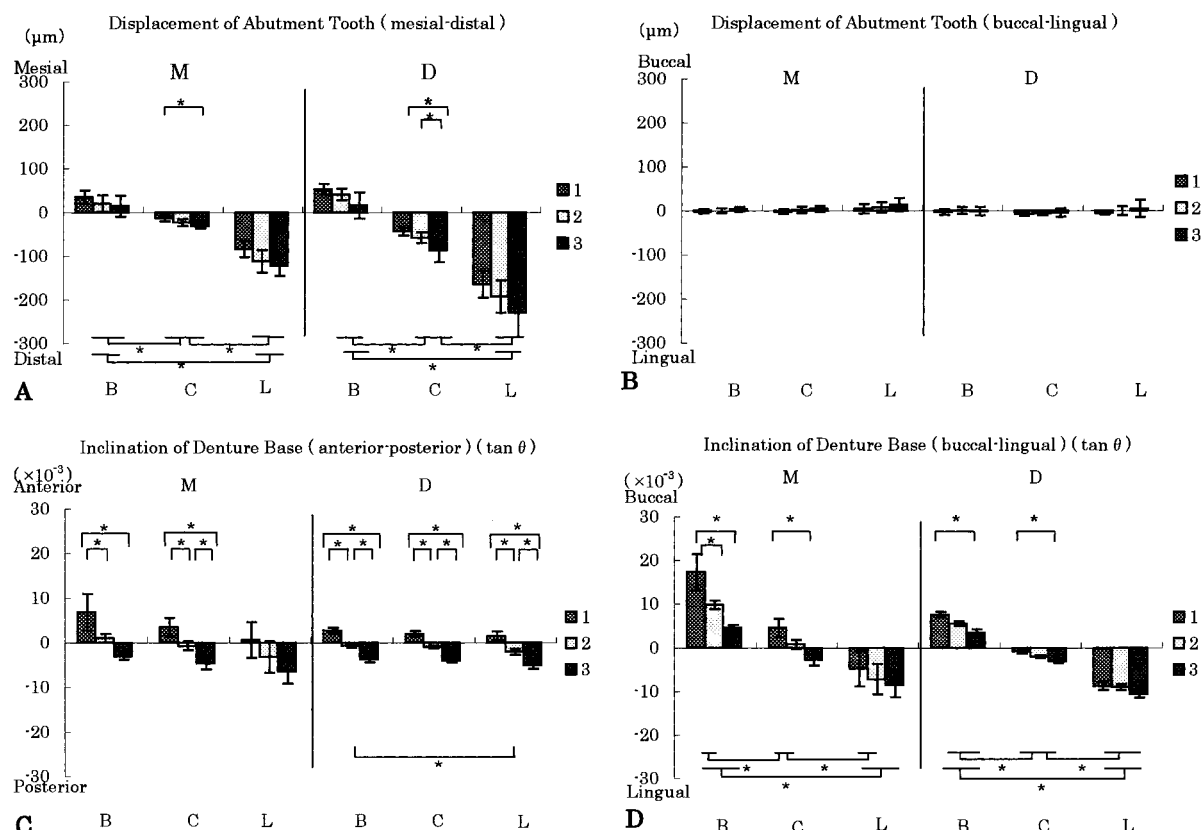
Fig. 5. Comparative analyses of movement of direct retainers (Type M and Type D). Displacement of abutment tooth, A: mesiodistal direction and B: buccolingual direction. Inclination of denture base, C: anteroposterior direction and D: buccolingual direction. M=Type M, D=Type D. B=Buccal, C=Central, L=Lingual, 1=Anterior, 2=Middle, 3=Posterior. * indicates significant difference (p< 0.05).

RPD with the least mobility of the abutment tooth. However, the results were inconclusive and sometimes contradictory.

Nally[4] demonstrated in his laboratory study that the mesial connection was always preferable if all displacements were taken into account. On the contrary, several studies[11,16] reported that clasp assemblies had no significant influences on the movement of the abutment tooth. Taylor[21] made comparative analyses between RPI clasp and distal Akers clasp and described that ideal adaptation of denture base over the residual ridge will result in less influence on the mobility of the abutment tooth regardless of clasp designs.

The findings of this study revealed that the central or lingual loading produced greater distal movement of the abutment tooth in Type D than Type M. The types of direct retainers utilized did not affect the directional but magnitudinal movements of the abutment tooth, which was consistent with the findings of Thompson et

al.[16] who described that RPD resulted in a distal torque of the abutment tooth regardless of clasp designs and that the magnitude was smaller at mesial rest than distal rest. Feingold et al.[11] reported conflicting results in their studies concerning the direction and magnitude of the abutment tooth using the clasp designs with different occlusal rest positions. They concluded that the directional movement of the abutment tooth was not related to the occlusal rest position, and the design of the clasp affected the magnitude of the movement of the saddle and the abutment tooth. These differences in magnitude of the movement of the abutment tooth can be explained with the difference in the structure of direct retainer (difference in position of the occlusal rest and the connection). That is to say, Type D, in which the distance from the occlusal rest to the loading point is shorter than that of Type M, which may result in a greater distal torque on the abutment tooth than Type M. As to the result, the magnitude of the displacement of the abutment tooth can be postu-

Fig. 6. Comparative analyses of movement in reference to loading points. Displacement of abutment tooth, A: mesiodistal direction and B: buccolingual direction. Inclination of denture base, C: anteroposterior direction and D: buccolingual direction. M=Type M, D=Type D. B=Buccal, C=Central, L=Lingual, 1=Anterior, 2=Middle, 3=Posterior.
* indicates significant difference ($p < 0.05$).

lated to be greater in Type D than in Type M. The difference of the position of the rest and the connection may also be a factor involved in the difference of the denture base displacement in the buccolingual direction. That is, the denture base of Type M elevated to the lingual side under buccal anterior loading (B1). The abutment tooth in Type M, however, slightly moved to the mesial direction and no significant difference between Type M and Type D were revealed. Therefore, the displacement of the denture base to the buccolingual direction under occlusal loading in this study was acceptable concerning the movement of the abutment tooth.

The directional movements of the abutment tooth and the denture base may involve influences of other factors rather than the clasp designs. Cecconi[3] identified four factors affecting RPD movement. They are: (1) the direction of load, (2) the type of load, (3) the ridge angle, and (4) the fit of the casting. We revealed in this study that the position of the loading point on the den-

ture base was also a major factor that influences the movement of the abutment tooth and denture base. Abutment tooth moved mesially under buccal (B) loading, and distally under the central (C) and lingual (L) loadings. Especially, the abutment tooth moved significantly more distally under posterior loading (C3) than under anterior loading (C1). Concerned with the inclination of the denture base, the more posteriorly the load applied, the more posteriorly the denture base inclined. From these results, position of loading point in the anteroposterior direction may influence the inclination of the denture base in the anteroposterior direction and abutment tooth movement to the mesiodistal direction. Increase in movement of the abutment tooth in the distal direction under posterior loading may result in harmful effects to the abutment tooth.

On the other hand, both types of the denture base inclined buccally under buccal loading and lingually under lingual loading. Concerned with the magnitude of inclination and depression of the denture base,

Table Mean values and standard deviations of denture base displacement. (μm)

Loading Point		Type of direct retainer	Anterior depression		Posteior depression		Buccal depression		Lingual depression	
Buccolingual	Anteroposterior		Mean	SD	Mean	SD	Mean	SD	Mean	SD
B	1	M	150	20	30	70	320	50	-30	30
		D	80	10	40	20	160	20	10	20
	2	M	110	10	90	30	200	30	20	10
		D	70	10	80	20	130	20	20	10
	3	M	80	10	130	20	130	30	40	10
		D	60	10	120	20	100	30	30	20
C	1	M	120	10	50	30	160	20	70	30
		D	90	10	50	10	80	10	90	10
	2	M	90	10	110	10	100	20	90	20
		D	80	10	90	10	60	10	100	10
	3	M	60	20	140	10	40	30	90	40
		D	60	10	130	10	30	20	90	10
L	1	M	90	40	80	30	40	20	140	100
		D	90	20	70	10	0	20	180	40
	2	M	70	40	120	20	-10	20	140	90
		D	80	20	110	10	-20	20	170	30
	3	M	40	40	160	10	-40	40	130	90
		D	60	20	160	20	-50	50	170	40

SD=standard deviation. Depression=+, Lifting= -.

B=Buccal, C=Central, L=Lingual. 1=Anterior, 2=Middle, 3=Posterior. M=Type M, D=Type D.

uneven distribution of work load on the residual ridge is postulated to be greater with elevation of the denture base to the buccal or lingual side. The difference of loading location influenced for standard deviation of the denture base displacement especially under lingual loadings (Table). In addition, the distal movement of the abutment was greater under lingual middle (L2) and lingual posterior (L3) loadings. Occlusal contact in the lingual posterior (L3) or central posterior (C3) region of the denture base results in unfavorable occlusal contacts regardless on the type of direct retainer utilized in distal extension RPD. Browning[5] revealed that there was no significant difference in the movement of the abutment tooth with three different clasp assemblies and that the abutment tooth moved buccally under buccal loading and lingually under lingual loading. This study coincides with the findings reported by Browning[5], which suggests that contacts around the distal region of the second molar produce harmful torque to the posterior abutment tooth.

That is, loading on the posterior region of the denture base resulted in inclination of the denture base to the posterior direction and postulated to have adverse effects due to unfavorable distribution of force on the abutment tooth and residual ridge.

The results of this study suggest that clinically we should give careful consideration to not only the clasp design but occlusal condition especially of posterior and lingual region of the denture base during function. In this study, the effects of direct retainers and location of occlusal loading in distal extension RPD were made clear. We need further study to clarify effects of other components such as indirect retainer and loading direction.

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