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EVALUATION OF THE RESIDUAL RIDGE AND DENTURE DESIGN IN RELATION TO THE LATERAL FORCE DISTRIBUTION TO THE ABUTMENT TEETH

In the case of unilateral extension saddle type removable partial denture prosthesis

BY

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ABSTRACT

This investigation was carried out for the purpose of analyzing the functional behavior of the removable partial denture with unilateral extension saddle, particularly to relationship between the denture design and the residual ridge form. For this purpose, four different types of residual ridges in clinically simulated mandibular models and three different types of testing dentures for each model were made. The previously reported special devices for measuring the tooth mobility, force applicator, and a micro-dial-gauge, and also their recording system were used. Using these systems, the amount of the lateral excursion of abutment tooth for the direct and indirect retainers was measured for three types of dentures on each model while a known force was applied on the occlusal table of the testing dentures. A personal computor was used for the statistical analysis of these data, and the conclusions were as follows:

i) The transmitting force to the abutment teeth was highly affected by the condition of residual ridge form and by denture designs while known vertical and lateral forces were applied on the occlusal table of the distal area.

ii) On the residual ridge with excess bucco-lingual bone loss, the so-called rocking axis of denture was located on the crest of the residual ridge, but location of the rocking axis was completely irregular on the residual ridge with excess bone loss in the second and third molar area.

iii) The twisting point or shifting axis on the occlusal table appeared as a spot in A-type denture and its location moved according to residual ridge conditions. This point or area on the occlusal table was moved greatly by the factor of the residual ridge when the B-type denture was applied.

iv) The amount of vertical excursion of the extension saddle-type denture against vertical loading was highly affected by denture design rather than by the residual ridge.

v) The location of the torque fulcrum of the free end saddle denture can also be changed by the denture design.

vi) The optimal occlusal pattern of the removable partial denture of the extension saddle type change with denture design and residual ridge.

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Introduction

The functional behaviour of mandibular distal extension saddle-type partial dentures and their appropriate design, based on the clinical and experimental foundation, have been incompletely established. The reviews and analysis of the pertinent literature[1-6] have revealed that further studies are necessary to establish the most appropriate theorized designs. Wearing of an extension saddle-type removable partial denture may create various problems in the presentation of periodontal structures of the abutment teeth and also the alveolar bone structure of residual ridge[7-9]. These problems can be alleviated by the optimal distribution of masticatory force to the abutment teeth and residual ridge. There are many literature on the types of clasp design recommended for the construction of an extension partial denture[10-25]. They are based on the premise that each type causes less tilting, tipping, torquing, and stress on the abutment tooth. These literature express the proper type of clasps mostly from empirical findings and lack clinical experimental data. There is also a lack of considerations about the relationship between the design and the condition of the residual ridge. Frechette[11] and the present author[5,6] investigated the effect of partial denture design on the distribution of vertical and lateral forces to the abutment teeth. They insisted that the loading and movement of abutment teeth are influenced by the number and location of the rests, contour, and rigidity of connectors, and extension of the denture bases. Kaires[12-14] showed almost the same results. Kaires and the present author[25] insisted from their experimental investigations that a decrease in the size of the occlusal table reduced vertical and horizontal stresses on the abutment teeth. Hofmann[15] investigated the abutment teeth kinematics under the influence of stress exercised on the prosthesis saddle at various points in 10 patients with unilateral free-end dentures. He reported that the rate and direction of these movements depended mainly on the point of application, the direction of the stress exerted, and the angle between the axis of a given tooth and its occlusal plane. Hindels[26] indicated in his conclusion that the magnitude and direction of the stresses to which the supporting structures will be subjected depend on the type of partial denture as well as on the design of its parts in relation to the anatomical form of supporting structures. Also, Frechette[11] has indicated that the design of the appliance plays an important part in the scheme, because it is through the structure of the denture that the force of mastication is transmitted from the occlusal surfaces of the artificial teeth to the natural teeth and residual ridges.

However, there are only incomplete investigations on the partial denture designs and residual ridge form in relation to the lateral force distribution to the abutment teeth in the case of removable partial dentures of unilateral mandibular extension saddle type. This investigation conducted under laboratory conditions had as its specific objective the analysis of the effect of partial denture design in relation to the residual ridge conditions.

For this purpose, determination of the magnitude of the forces imparted to abutment teeth by differently designed dentures on different residual ridge conditions, in clinically simulated models, also the relative movement of the abutment teeth in a horizontal plane, and vertical excursion of the denture saddle were analyzed while a known force was applied on the occlusal table of the testing dentures.

Materials and Methods

For this investigation, four different types of clinically simulated mandibular arch were fabricated. These simulated models were constructed of clear methyle methacrylate, and 1.0 to 2.0 mm of Silicone rubber (Silastic 390) were coated to make the tooth-supporting tissue and residual ridge conditions. These models adequately permitted the physiological mobility of teeth and exhibited optimal resiliencies of the mucosa of residual ridges. The tooth mobility of these simulated models was considerably near the optimal condition for this investigation. Also, the resiliencies of the mucosa precisely followed Sato's and Rehm's data[21-22] which were measured in clinical intra-oral examinations. The arches of the simulated models were

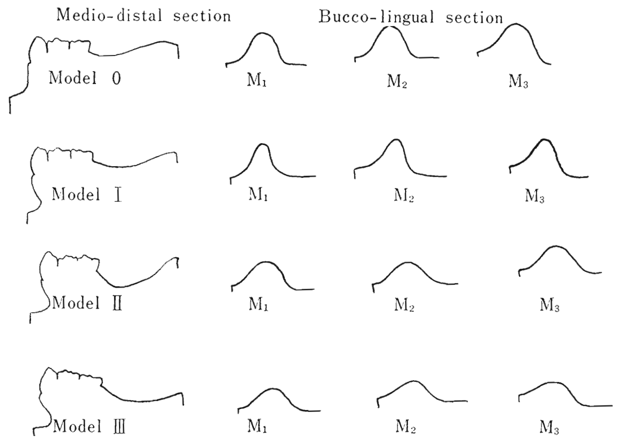

Fig. 1. Medio-distal and bucco-lingual sections of four types simulated mandibular models.

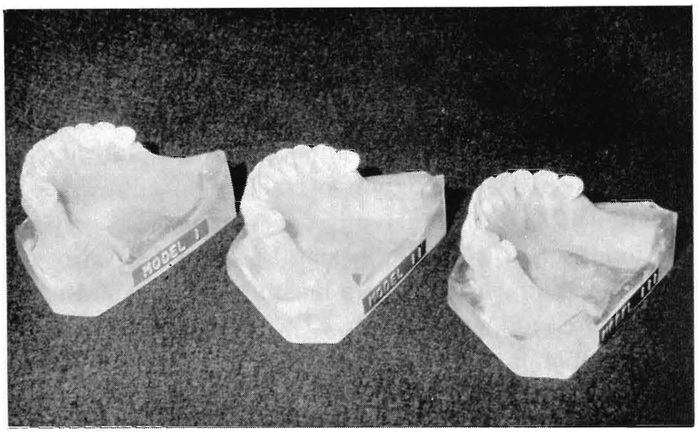

Fig. 2. Simulated residual ridges with excess bone loss in three types.

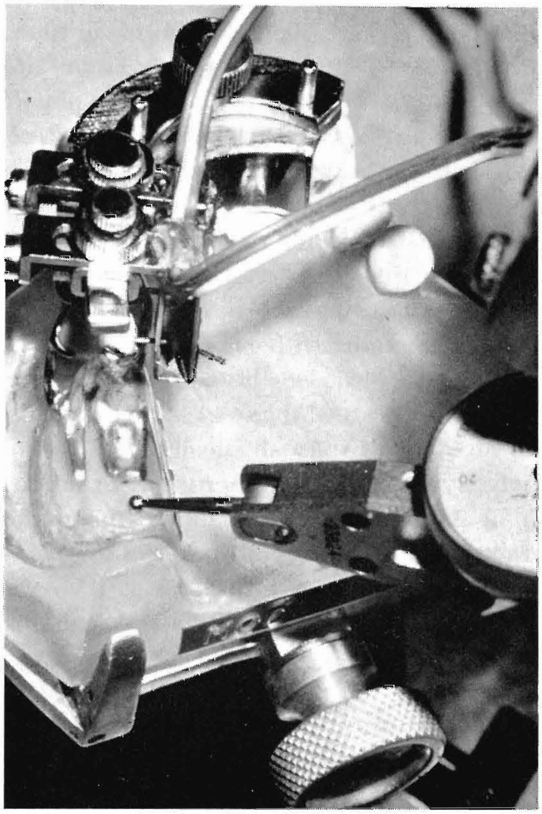

Fig. 3. Tooth mobility indicators and a micro-dial-gauge on the simulated model.

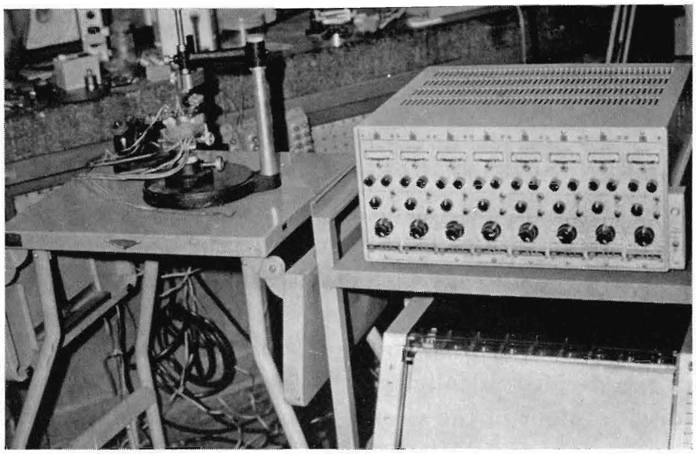

Fig. 4. Experimental appliances and their recording systems.

edentulous in the bilateral first and second molar area. Four types of residual ridge of the simulators were modified from several clinical cases of the patients. These are divided into the four following types: Model 0, minimal loss of residual bone, in clinically good condition; Model I, bucco-lingually narrowed, clinically poor; Model II, excess bone loss in the first molar area; Model III, excessive loss of alveolar bone in the second and third molar area. These are shown in Figs. 1 and 2.

For each of these four types of partially edentulous mandibular simulated models, three types of removable partial denture of unilateral extension saddle type were designed. These three types of designs and constructions of the dentures were the same as in the previous investigations, as shown in each table and chart paper. The devices for measuring and recording the lateral excursion of the abutment tooth were the same as those reported previously[5,6,23,24,25]. A load application transducer was used for application of the known force. In this investigation, a special micro-dial-gauge was subjoined for checking the vertical excursion of free-end saddle of the testing dentures while a known force was applied on their occlusal table. (Figs. 3 and 4). Using these devices, the amount of lateral excursion of the abutment tooth and vertical denture mobility were analyzed while known vertical and lateral forces were applied on the occlusal table of the testing dentures. For giving the vertical forces on the occlusal table, nine points were decided as shown in each figure. In order to give a clinically simulated intra-oral condition, glycerol was applied between the silastic soft tissue and denture saddle, as a salivary coating.

Results

Application of vertical forces on the occlusal table: A part of graphic chart paper of this experiment and statistically analyzed table are shown for each type of testing denture with each model. The amount of excursion of abutment tooth of the second premolar as the direct retainer and the first premolar as indirect retainer was recorded, while the 500 g vertical force was applied on the previously decided nine points on the occlusal table. These nine points were located on the occlusal table placed on the same level as the occlusal plane of the simulated mandibular arch, this occlusal table was 15 mm in bucco-lingual width, and the artificial denture tooth area was decided as follows: The first molar area was 5 mm distal from the distal contour of the second premolar, in 15 mm distal area from the same point as the second molar, and in 25 mm distal area as the third molar. On each tooth area, further three points were taken up as follows: The crest spot was on the center of the bucco-lingual width of the occlusal table, the buccal spot was in 5 mm buccal side from the crest spot, and the lingual spot in 5 mm lingual side from the crest spot. The amount of lateral excursion of the abutment teeth and the vertical excursion of the free-end saddle were recorded simultaneously on a pen-writing oscillograph paper and micro-dial-gauge while 500 g vertical force was applied on each of the nine points by the force applicator. These results were as follows:

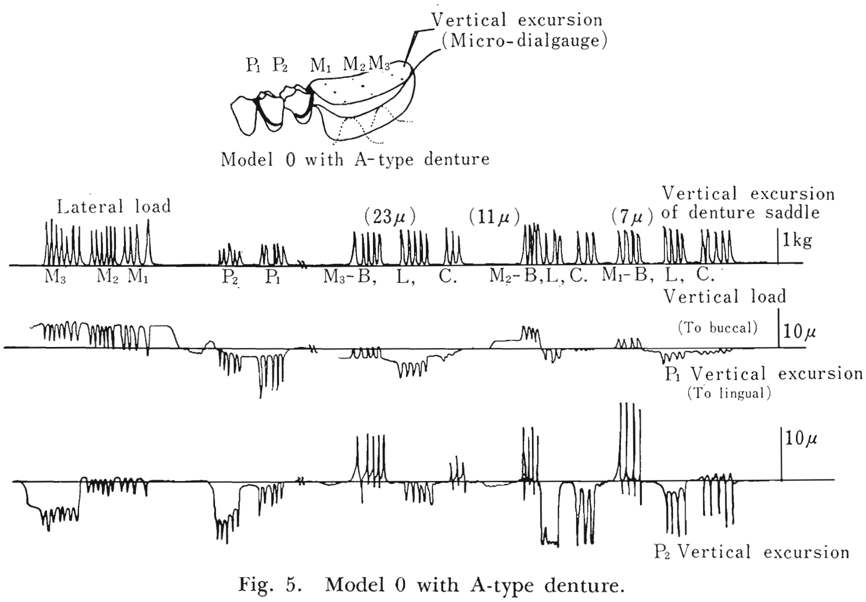

Fig. 5. Model 0 with A-type denture.

Table 1. Model 0 with A-type denture

Loading point (500g vertical load)	Lateral excursion: P_1 (Indirect retainer)		Lateral excursion: P_2 (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B	−1.9	0.3	−6.7	0.2	
M_1–C	0.5	0.0	4.4	0.3	6.8
M_1–L	1.3	0.3	5.2	0.3	
M_2–B	−2.4	0.1	−4.4	0.2	
M_2–C	0.5	0.0	5.5	0.0	11.4
M_2–L	1.9	0.4	8.0	0.0	
M_3–B	−1.8	0.0	−5.0	0.0	
M_3–C	0.9	0.4	2.0	0.3	22.7
M_3–L	2.8	0.4	2.2	0.2	
(100g virtical load)					
P_1	4.5	0.4	1.9	0.5	
P_2	3.4	0.2	5.2	0.3	
M_1	1.3	0.1	0.7	0.1	
M_2	1.2	0.1	0.8	0.1	
M_3	0.8	0.1	1.9	0.2	
(Without denture)					
P_1	10.4	0.4			
P_2			10.2	0.8	

Table 2. Model I with A-type denture

Loading point (500g vertical load)	Lateral excursion: P_1 (Indirect retainer)		Lateral excursion: P_2 (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B	1.3	0.1	2.2	0.2	
M_1–C	2.6	0.4	5.1	0.1	21.0
M_1–L	2.7	0.4	5·1	0.6	
M_2–B	−1.6	0.1	0.8	0.1	
M_2–C	−2.6	0.4	1.6	0.2	39.0
M_2–L	0.7	0.1	2.7	0.2	
M_3–B	−8.0	0.3	−3.9	0.6	
M_3–C	−4.4	0.2	−1.3	0.4	76.1
M_3–L	−2.8	0.2	1.7	0.1	
(100g lateral load)					
P_1	4.1	0.7	3.8	0.8	
P_2	2.1	0.9	2.6	1.2	
M_1	1.5	0.0	1.5	0.1	
M_2	0.8	0.0	1.0	0.0	
M_3	0.5	0.2	−1.7	0.5	
(Without denture)					
P_1	10.0	0.0			
P_2			10.0	0.0	

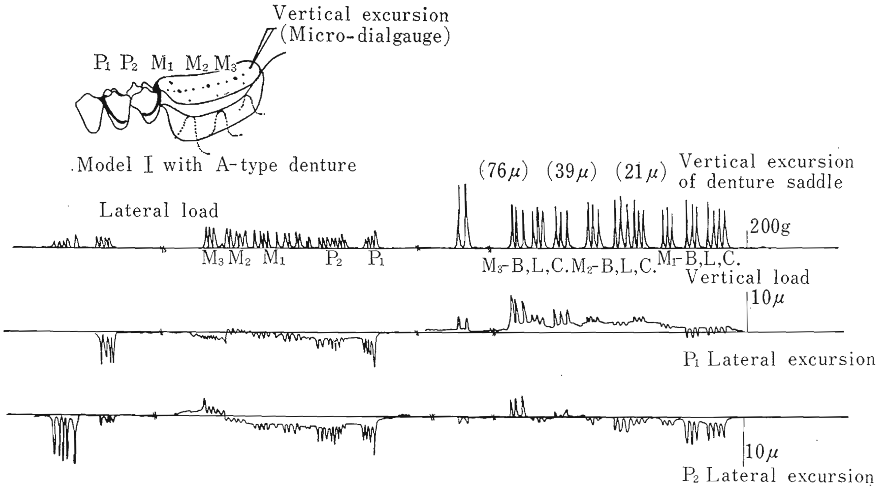

Fig. 6. Model I with A-type denture.

A-Type Denture:

1. Model 0: Minimal bone loss, clinically good (Fig. 5 and Table 1)

i) Vertical Loading: There was rather a large difference in the lateral excursion of direct and indirect retainers, but the direction of the excursion path was almost the same. The vertical excursion of a denture saddle was about 7 micra, when a 500 g vertical load was applied on the first molar area, but about three times larger amount of excursion, 23 micra, was observed when the same amount of load was applied on the third molar area on the occlusal table of this testing denture.

ii) Lateral Loading: The amount of lateral excursion in the direct retainer increased markedly when the lateral load was applied on the distal area as in the third molar area, but the amount of indirect retainer conversely decreased.

2. Model I: Bucco-lingual bone loss (Fig. 6 and Table 2)

i) Vertical Loading: The amount of lateral excursion of abutment tooth of direct retainer, when a vertical load was applied on the distal area of the occlusal table, was smaller than that of proximal loading. For the abutment tooth of the indirect retainer, the amount of lateral excursion was completely reverse of that of the direct retainer.

ii) Lateral Loading: The direction of lateral excursion path in the direct retainer changed from lingual to buccal when the lateral load was applied on the third molar area.

3. Model II: Excess bone loss in the first molar area (Figs. 7 and 8, and Table 3)

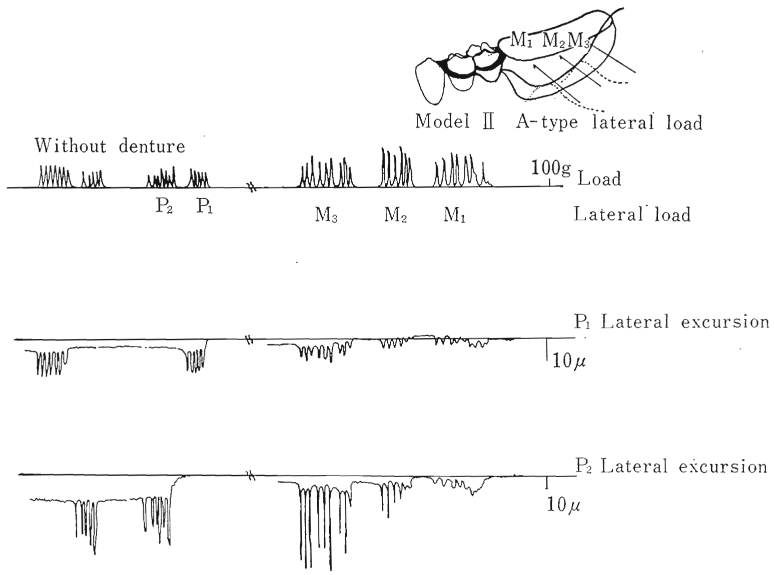

Fig. 7. Model II with A-type denture.

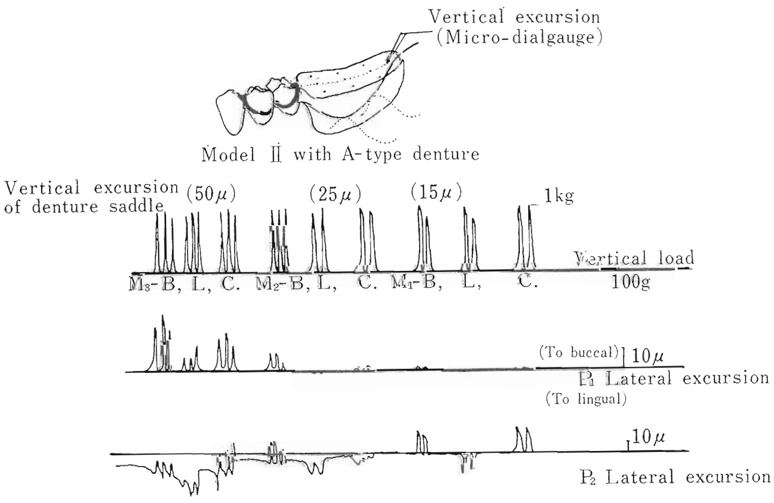

Fig. 8. Model II with A-type denture.

i) Vertical Loading: This type of residual ridge was most familiar in routine clinics. In this case, when a vertical load was applied on the lingual or buccal point in the distal area, as the third molar area, the amount of lateral excursion of the abutment tooth increased markedly.

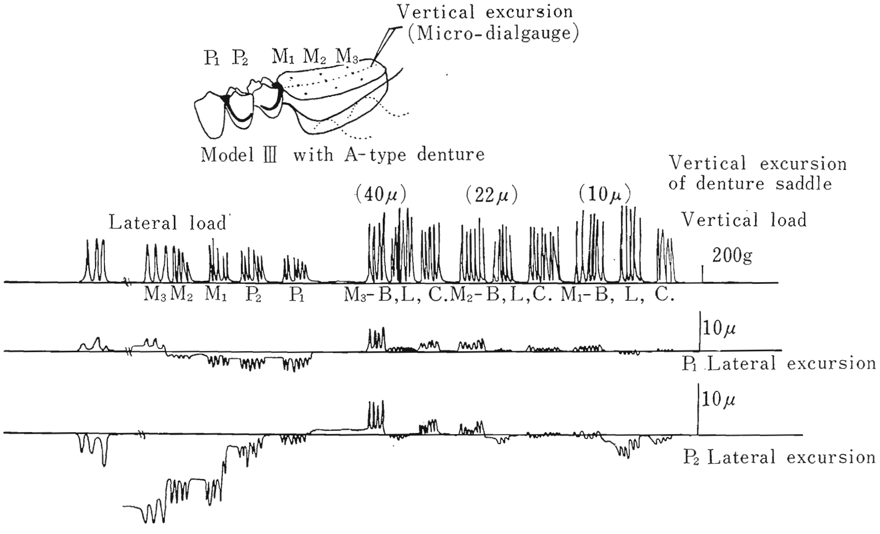

Fig. 9. Model III with A-type denture.

Table 3. Model II with A-type denture

Loading point (500g vertical load)	Lateral excursion: P_1 (Indirect retainer) M.	±S.D.	Lateral excursion: P_2 (Direct retainer) M.	±S.D.	Vertical excursion of denture saddle (μ)
M_1–B	− 1.3	0.3	−10.4	0.7	
M_1–C	0.3	0.1	− 8.3	2.4	15.0
M_1–L	0.1	0.1	7.1	2.5	
M_2–B	− 2.9	0.1	− 8.5	2.6	
M_2–C	− 1.2	0.3	3.8	0.3	25.0
M_2–L	0.5	0.0	7.0	0.0	
M_3–B	−12.9	1.9	− 5.2	0.3	
M_3–C	− 7.4	1.2	− 9.8	0.3	50.0
M_3–L	4.3	0.6	11.7	2.9	
(100g lateral load)					
P_1	3.4	0.6	1.6	0.6	
P_2	2.8	0.4	2.4	0.9	
M_1	5.0	1.7	5.5	1.8	
M_2	7.0	0.0	7.6	0.9	
M_3	4.0	1.0	9.4	0.7	
(Without denture)					
P_1	8.0	1.4			
P_2			13.0	1.8	

ii) Lateral Loading: The amount of lateral excursion of the abutment tooth, increased markedly when a lateral load was applied on the distal area.

Table 4. Model III with A-type denture

Loading point (500g vertical load)	Lateral excursion P_1 (Indirect retainer) M.±S.D.		Lateral excursion P_2 (Direct retainer) M.±S.D.		Vertical excursion of denture saddle (μ)
M_1–B	−1.9	0.1	−1.5	0.1	
M_1–C	−1.1	0.1	1.9	0.3	10.4
M_1–L	0.8	0.2	3.1	0.3	
M_2–B	−3.8	0.7	4.0	0.3	
M_2–C	1.2	0.1	−0.9	0.1	22.0
M_2–L	−0.4	0.1	3.1	0.2	
M_3–B	−6.7	0.2	−7.6	0.4	
M_3–C	−3.5	0.6	3.5	1.0	40.0
M_3–L	−1.2	0.1	1.2	0.1	
(100g lateral load)					
P_1	2.8	0.3	1.4	0.1	
P_2	1.6	0.3	2.1	0.5	
M_1	1.2	0.2	5.9	1.6	
M_2	0.9	0.3	8.2	2.3	
M_3	−1.4	0.0	7.4	0.4	

Table 5. Model 0 with B-type denture

Loading point (500g vertical load)	Lateral excursion P_1 (Indirect retainer) M.±S.D.		Lateral excursion P_2 (Direct retainer) M.±S.D.		Vertical excursion of denture saddle (μ)
M_1–B	−1.5	0.1	4.7	0.5	
M_1–C	0.7	0.1	8.9	0.1	40.0
M_1–L	1.8	0.5	7.8	0.3	
M_2–B	−3.2	0.1	4.3	0.5	
M_2–C	0.4	0.0	7.9	0.3	51.0
M_2–L	2.3	0.2	6.6	0.6	
M_3–B	−3.2	0.4	5.9	0.3	
M_3–C	−0.2	0.0	3.8	0.0	72.2
M_3–L	−4.4	0.0	2.9	0.0	
(100g lateral load)					
P_1	4.1	0.3	2.3	0.0	
P_2	1.5	0.0	3.2	0.3	
M_1	4.1	0.1	2.7	0.0	
M_2	2.3	0.4	2.4	0.1	
M_3	1.3	0.2	3.3	0.7	

4. Model III: Excess bone loss in the second and the third molar area (Fig. 9 and Table 4)

i) Vertical Loading: When a vertical loading was applied on the first molar area, the lateral excursion of the abutment tooth was rather stable

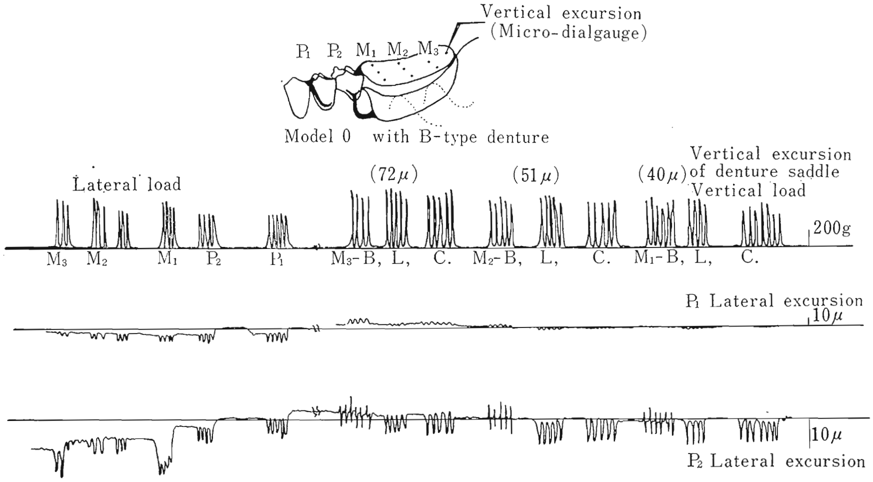

Fig. 10. Model 0 with B-type denture.

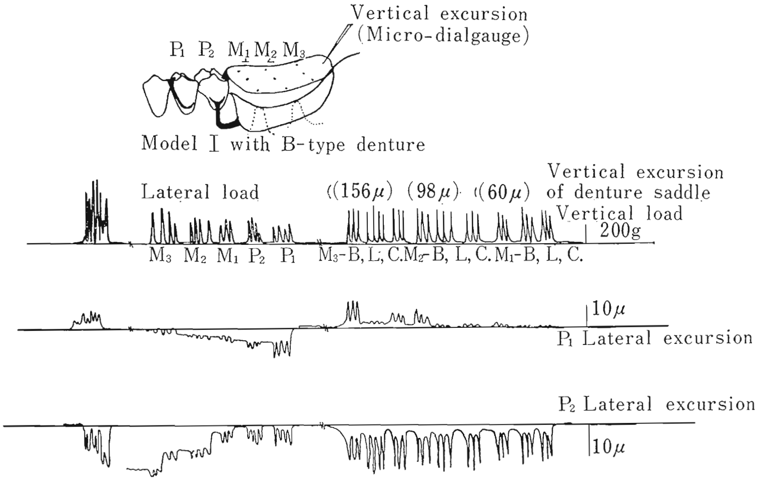

Fig. 11. Model I with B-type denture.

but increased markedly when the load was applied on the third molar area.

ii) Lateral Loading: Almost the same result as the vertical loading was obtained.

B-Type Denture:

1. Model 0 (Fig. 10 and Table 5)

i) Vertical Loading: Lateral excursion of the indirect retainer increased when a vertical load was applied on the distal area of the occlusal table, but that of the direct retainer decreased conversely.

Table 6. Model I with B-type denture

Loading point (500μ vertical load)	Lateral excursion P_1 (Indirect retainer)		Lateral excursion P_2 (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B	−3.7	0.4	15.9	0.9	
M_1–C	2.2	0.2	19.6	0.4	60.4
M_1–L	3.0	0.4	19.8	0.2	
M_2–B	−6.7	0.9	14.9	2.1	
M_2–C	−2.8	0.4	19.9	0.4	97.8
M_2–L	2.1	0.0	21.7	0.0	
M_3–B	−15.6	1.0	14.0	0.9	
M_3–C	−5.5	0.3	17.5	0.0	155.7
M_3–L	−2.0	0.3	22.2	2.8	
(100g Lateral Load)					
P_1	6.6	0.7	3.8	1.0	
P_2	4.0	0.6	3.0	1.4	
M_1	2.1	0.2	2.0	0.6	
M_2	1.5	0.1	3.8	0.6	
M_3	0.7	0.3	4.3	0.2	

Table 7. Model II with B-type denture

Loading point (500μ vertical load)	Lateral excursion P_1 (Indirect retainer)		Lateral excursion P_2 (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B	−0.5	0.2	8.0	1.2	
M_1–C	0.0	0.0	8.9	0.4	40.0
M_1–L	0.5	0.0	10.5	0.5	
M_2–B	−0.7	0.1	10.1	1.3	
M_2–C	0.0	0.0	12.6	1.3	63.3
M_2–L	0.5	0.1	11.8	0.6	
M_3–B	−1.2	0.0	14.6	0.0	
M_3–C	0.0	0.0	13.6	0.0	110.00
M_3–L	0.6	0.1	12.3	0.9	
(100g lateral load)					
P_1	0.3	0.0	1.7	0.0	
P_2	2.6	0.1	3.4	0.2	
M_1	0.0	0.0	2.3	0.3	
M_2	0.4	0.0	2.4	0.0	
M_3	0.4	0.0	2.6	0.0	

ii) Lateral Loading: By lateral loading in the distal area, the amount of lateral excursion of direct and indirect retainers was reverse of each other, that of the direct retainer increased and that of the indirect retainer decreased.

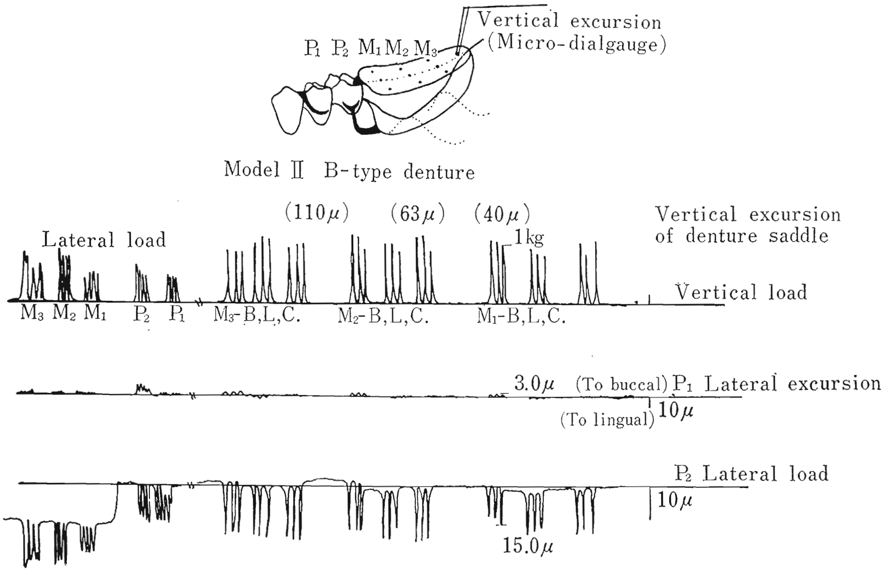

Fig. 12. Model II with B-type denture.

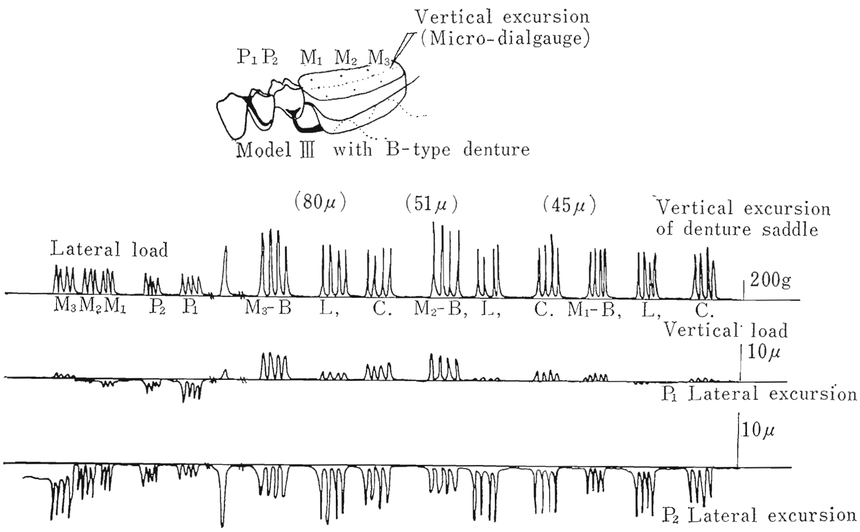

Fig. 13. Model III with B-type denture.

2. Model I (Fig. 11 and Table 6):

i) Vertical Loading: In this case, the excursion path of the abutment tooth was only towards buccal to lingual. When a vertical load was applied on the distal area of the occlusal table, the amount of that in indirect retainer increased.

Table 8. Model III with B-type denture

Loading point (500g vertical load)	Lateral excursion P_1 (Indirect retainer)	 P_2 (Direct retainer)	Vertical excursion of denture saddle (μ)
	M.±S.D.	M.±S.D.	
M_1–B	− 3.8 0.2	7.7 0.3	
M_1–C	− 2.0 0.3	12.2 0.6	45.0
M_1–L	0.5 0.0	15.6 0.9	
M_2–B	− 5.6 0.0	5.1 0.2	
M_2–C	− 3.5 0.2	14.1 1.4	51.0
M_2–L	− 1.3 0.2	16.8 2.1	
M_3–B	−10.6 0.7	9.4 0.6	
M_3–C	− 6.6 0.5	11.9 1.2	80.4
M_3–L	− 3.3 0.1	17.9 2.9	
(100g lateral load)			
P_1	3.6 0.3	2.2 0.4	
P_2	2.1 0.4	3.6 0.7	
M_1	0.7 0.1	3.6 0.3	
M_2	0.0 0.0	4.2 0.5	
M_3	− 1.4 0.1	6.5 0.2	

Table 9. Model I with C-type denture

Loading point (500g vertical load)	Lateral excursion P_1 (Indirect retainer)	 P_2 (Direct retainer)	Vertical excursion of denture saddle (μ)
	M.±S.D.	M.±S.D.	
M_1–B		40.8 0.9	
M_1–C		34.5 3.7	96.8
M_1–L		37.5 0.0	
M_2–B		39.9 2.1	
M_2–C		40.8 0.9	145.2
M_2–L		37.6 1.8	
M_3–B		38.8 2.2	
M_3–C		36.4 1.6	234.4
M_3–L		34.6 0.4	
(100g lateral load)			
P_2		5.2 0.8	
M_1		4.6 0.6	
M_2		5.9 0.5	
M_3		7.8 0.8	

3. Model II (Fig. 12 and Table 7):

i) Vertical Loading: A rather large amount of lateral excursion of abutment teeth was observed in this case, and the difference in the amount between direct and indirect retainers was remarkably large.

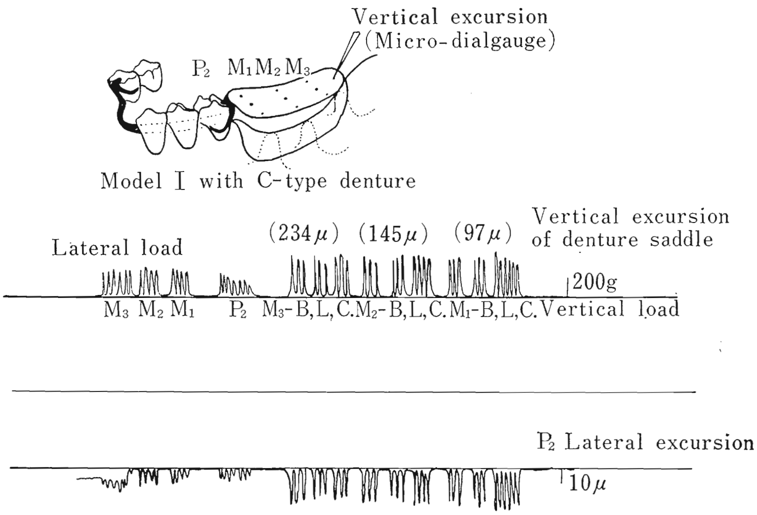

Fig. 14. Model I with C-type denture.

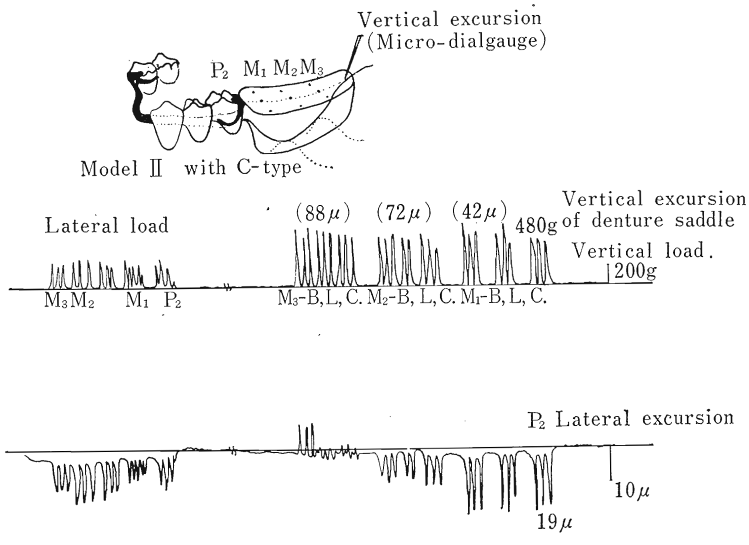

Fig. 15. Model II with C-type denture.

ii) Lateral Loading: A markedly large amount of lateral excursion was observed in the abutment of direct retainer, but it was smaller in the indirect retainer.

4. Model III (Fig. 13 and Table 8):

i) Vertical Loading: In this case the maximal amount of lateral excursion was observed.

Table 10. Model II with C-type denture

Loading point (500g vertical load)	Lateral excursion P₁ (Indirect retainer)		Lateral excursion P₂ (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B			14.6	0.8	
M_1–C			19.4	0.3	42.2
M_1–L			14.5	0.6	
M_2–B			6.7	0.0	
M_2–C			9.7	1.5	72.1
M_2–L			7.9	0.7	
M_3–B			−6.9	0.0	
M_3–C			2.3	0.4	87.6
M_3–L			1.9	0.0	
(100g lateral load)					
P_2			3.7	0.3	
M_1			3.2	0.6	
M_2			4.2	0.3	
M_3			4.2	0.2	

Table 11. Model III with C-type denture

Loading point (500g vertical load)	Lateral excursion P₁ (Indirect retainer)		Lateral excursion P₂ (Direct retainer)		Vertical excursion of denture saddle (μ)
	M.	±S.D.	M.	±S.D.	
M_1–B			9.7	0.3	
M_1–C			10.8	0.5	46.0
M_1–L			11.4	0.9	
M_2–B			8.5	0.9	
M_2–C			9.4	1.1	63.0
M_2–L			10.1	0.5	
M_3–B			7.9	0.3	
M_3–C			8.7	0.2	71.0
M_3–L			9.5	1.2	
(100g lateral load)					
P_2			1.7	0.1	
M_1			2.1	0.4	
M_2			2.4	0.3	
M_3			3.0	0.1	
(Without denture)					
P_1	4.9	0.3			
P_2			8.3	1.0	

C-Type Denture:

1. Model I (Fig. 14 and Table 9):

   i) Vertical Loading: C-type denture was not fabricated for Model 0.

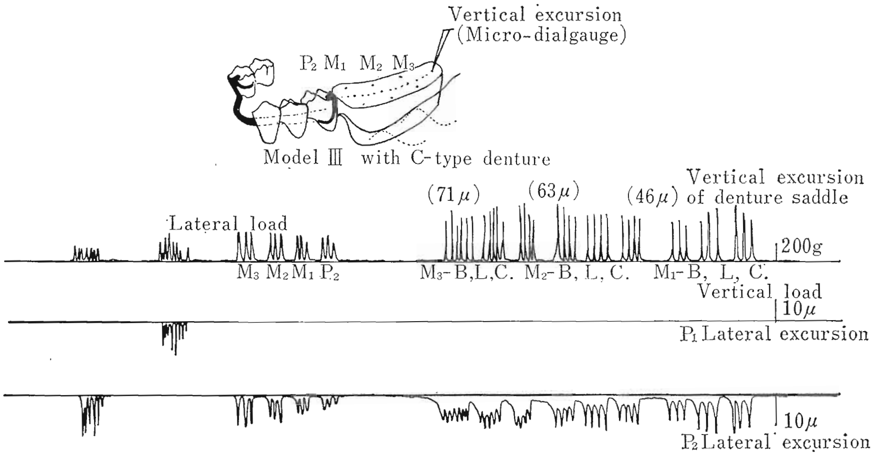

Fig. 16. Model III with C-type denture.

In this case, only the excursion of the second premolar was observed. A rather large amount of vertical excursion of the denture saddle was observed in this type denture, and lateral excursion of the direct retainer was almost constant even when the location of the loading points was changed.

ii) Lateral Loading: In this case, a small amount of lateral excursion of abutment tooth was observed.

2. Model II (Fig. 15 and Table 10):

i) Vertical Loading: The results in this case were almost the same as that of Model I, but a less lateral excursion was observed, especially by distal loading.

ii) Lateral Loading: The results were almost the same as those of Model I.

3. Model III (Fig. 16 and Table 11):

i) Vertical Loading: The amount of lateral excursion was rather small.

ii) Lateral Loading: The results were almost the same as with other models.

Discussion

For the purpose of analyzing the denture design in relation to the residual ridge form, the amount of force transmitted from the denture to the abutment teeth was examined by using specially deviced simulated mandibular models and electrical tooth mobility indicator systems, reported

Table 12. Coefficient of correlation between the amount of lateral excursion in the indirect retainer (P_1) and the direct retainer (P_2)

	Vertical loading			
	M–0	M–I	M–II	M–III
A-type denture	0.84**	0.95**	0.51	0.45
B-type denture	0.71*	0.79	−0.09	0.56
	Lateral loading			
A-type denture	−0.52	0.87*	−0.29	−0.82
B-type denture	−0.52	−0.92**	0.76	−0.99**

* 5% confidence level ** 1% confidence level

Table 13. Coefficient of correlation between the amount of lateral excursion in the first premolar (P_1) by vertical loading on the occlusal table

		A-type denture				B-type denture			
		M–0	M–I	M–II	M–III	M–0	M–I	M–II	M–III
A-type	M–0		0.22	0.57	0.60	0.36			
	M–I			0.72*	0.71*		0.88*		
	M–II				0.81**			0.78*	
	M–III								0.91**
B-type	M–0						0.67*	0.48	0.63
	M–I							0.85**	0.81**
	M–II								0.91*
	M–III								

* Significance in 1% level of confidence
** ,, 5% level of confidence

Table 14. Coefficient of correlation between the amount of lateral excursion in the second premolar (P_2) by vertical loading on the occlusal table

	A-type denture				B-type denture				C-type denture		
	M–0	M–I	M–II	M–III	M–0	M–I	M–II	M–III	M–I	M–II	M–III
A-type											
M–0		0.53	0.63	0.49	0.50						
M–I			0.31	0.58		0.61			−0.26		
M–II				0.14			0.27			−0.07	
M–III								0.22			0.46
B-type											
M–0						0.22	−0.21	0.19			
M–I							−0.14	0.28	−0.54		
M–II								0.22		−0.86**	
M–III											0.52
C-type											
M–I										−0.03	−0.34
M–II											0.82**
M–III											

* 5% confidence level ** 1% confidence level

Table 15. Coefficient of correlation between the amount of lateral excursion in the first premolar (P_1) by a lateral loading

		A-type denture				B-type denture			
		M–0	M–I	M–II	M–III	M–0	M–I	M–II	M–III
A-type	M–0		0.95*	−0.64	0.82	0.33			
	M–I			−0.54	0.85*		0.99*		
	M–II				0.19			−0.54	
	M–III								0.94*
B-type	M–0						0.50	−0.57	0.54
	M–I							0.22	0.28
	M–II								0.94*
	M–III								

* 5% confidence level ** 1% confidence level

Table 16. Coefficient of correlation between the amount of lateral excursion in the second premolar (P_2) by a lateral loading

	A-type denture				B-type denture				C-type denture		
	M–0	M–I	M–II	M–III	M–0	M–I	M–II	M–III	M–I	M–II	M–III
A-type											
M–0		0.28	−0.51	−0.63	0.57						
M–I			−0.95**	−0.82*		−0.35			−0.96**		
M–II				0.96**			0.06			0.61	
M–III								0.72			0.80
B-type											
M–0						0.04	0.78	0.68			
M–I							0.05	0.36	0.91*		
M–II								0.77		0.02	
M–III											0.92**
C-type											
M–I											
M–II										0.81	0.88*
M–III											0.64

previously. In the present investigation, statistical analysis of these experimental data was made by the computer system. The coefficient of correlation was computed between the amount of lateral excursion of the first premolar, the indirect retainer, and that of the second premolar, direct retainer, while known vertical and lateral forces were applied on the testing dentures. These results are shown in Table 12. In these results, rather a large difference was observed in the values of coefficiency depending on the residual ridge form, even though the denture design was the same. They had nothing in common with each other, even in the same type denture, nor on the same simulated model. The coefficient correlation matrix on the amount of lateral excursion of the abutment teeth between the denture group and the residual ridge group was examined by a computer.

These results are shown in Tables 13 to 16. The coefficient correlation of the first premolar, as indirect retainer, by vertical loading indicated a high significance against the factor of residual ridge form rather than the factor of denture design. However, those of the second premolar, as the direct retainer, was less significant against both the denture design and residual ridge condition. When a lateral load was applied, the most remarkable result was the appearance of a negative coefficient correlation against both the denture design and residual ridge condition. These results indicated that the lateral excursion of the second premolar, as the direct retainer, would be highly influenced by small changes in the residual ridge condition and denture design.

In order to understand these complicated results on the amount of lateral excursion of abutment teeth as the index of transmitting force against the abutment teeth while a vertical force was applied on the occlusal table of each testing denture on each differently shaped residual ridges, quantitative diagrams of the most optimal occlusal table pattern and the shifting points or line, or area were indicated as shown in Fig. 17.

These patterns were plotted by observing the minimal lateral excursion of the abutment teeth on the recording chart papers. With respect to the lateral force from the buccal to lingual acting on the artificial tooth area of the denture saddle, the excursion of abutment teeth was greatly affected in the direct retainer, and markedly larger amount of excursion of abutments was indicated, especially by the distal loading.

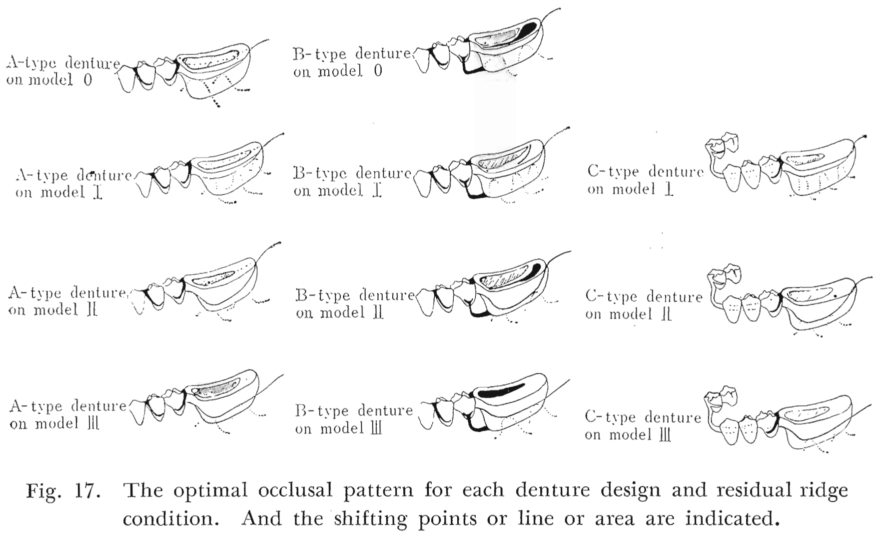

Fig. 17. The optimal occlusal pattern for each denture design and residual ridge condition. And the shifting points or line or area are indicated.

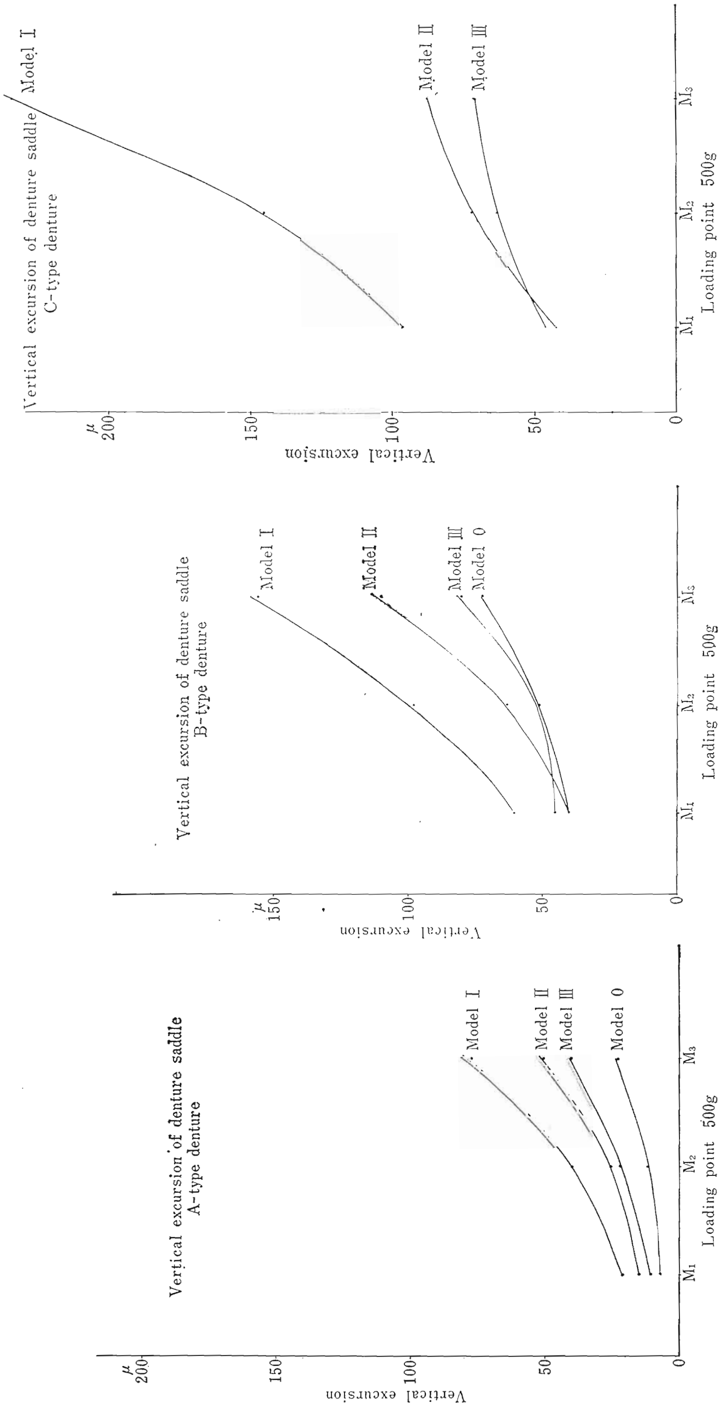

Fig. 18. The vertical excursion of the distal extension saddle of unilateral removable denture against vertical loads on the occlusal table.

The results of the vertical excursion of the distal extension saddle-type denture the so-called denture mobility, are shown in Fig. 18. These diagrams clearly indicate that the amount of denture mobility will be more intimately affected by denture design rather than by residual ridge conditions.

The most interesting result from these graphic curves was that the distal end of the occlusal rest of the direct retainer would not represent the location of torquing fulcrum of denture mobility.

CONCLUSION

This investigation was carried out for the purpose of analyzing the functional behaviour of the removable partial denture with unilateral extension saddle, particularly the relationship between the denture design and the residual ridge form. For this purpose, four different types of residual ridge in clinically simulated mandibular model and three different types of testing dentures for each model were fabricated. The specially devised tooth mobility indicator, force applicator, and a micro-dial-gauge, and also their recording system employed the same as those previously reported. Using these systems, the amount of lateral excursion of the abutment tooth for the direct and indirect retainers was measured in three types of dentures on each model while a known force was applied on the occlusal table of the testing dentures. A personal computer was used for the statistical analysis of these data. The conclusions drawn were as follows:

i) The force transmitted to the abutment teeth was highly affected by the condition of residual ridge and denture design while a known force was applied to the occlusal table of the free-end type removable partial denture.

ii) On the residual ridge with excess bucco-lingual bone loss, the so-called rocking axis of denture was located on the crest of the residual ridge, but the appearance of the rocking axis was completely irregular in the ridge with excess bone loss in the second and third molar area.

iii) The twisting point or shifting axis on the occlusal table appeared as a spot in A-Type denture, and its location changed with residual ridge form. This point or area for B-Type denture was greatly changed by the residual ridge condition.

iv) The amount of vertical excursion of the extension saddle-type denture against vertical loading was more highly affected by denture design than the residual ridge condition.

v) The optimal occlusal pattern of the extension saddle-type removable partial denture must be decided by denture design and the condition of the residual ridge.

vi) The location of the torque fulcrum of the extension saddle-type removable partial denture will be changed by the denture design.

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