Bull. Tokyo Med. Dent. Univ., 19: 301–310, 1972.

LATERAL FORCE DISTRIBUTION WITH RELATION TO THE RESIDUAL RIDGE FORM AND DENTURE DESIGN

In the unilateral mandibular extension saddle-type removable partial denture prosthesis

BY

Makoto MATSUMOTO, Tadamasa GOTO and Teruo TATEISHI*1

ABSTRACT

This investigation was carried out to analyze the lateral force distribution of the unilateral extension saddle partial denture, particularly the relationship between the denture design and the residual ridge form. For this purpose, the previously reported materials and experimental equipments were used.

Conclusions were as follows: (i) The lateral load distribution was highly affected by the condition of residual ridge and the denture design. (ii) When the condition of residual ridge tends to be clinically poor, with excess bone loss, cross arch-designed indirect retainer highly withstands lateral load distributions.

INTRODUCTION

This report is a supplement of the previous paper[1]. This investigation conducted under laboratory conditions had, as its specific objective, analysis of the effect of partial denture design in relation to the residual ridge conditions. For this purpose, determination of the magnitude of the transmitting lateral forces imparted to abutment teeth by differently designed partial dentures on different residual ridge conditions, in clinically simulated models, and the relative movement of the abutment teeth in a horizontal plane were analyzed while a known lateral force was applied on the denture saddle of the testing dentures.

MATERIALS AND METHODS

Materials and methods used in this experiment were completely the same as in the previous work[1]. Four types of residual ridge of the simula-

---

*1 松元 誠, 後藤忠正, 健石照雄: Department of Prosthetic Dentistry (Chief. Prof. I. NAKAZAWA), School of Dentistry, Tokyo Medical and Dental University (Tokyo Ika Shika Daigaku).

Received for publication, June 13, 1972.

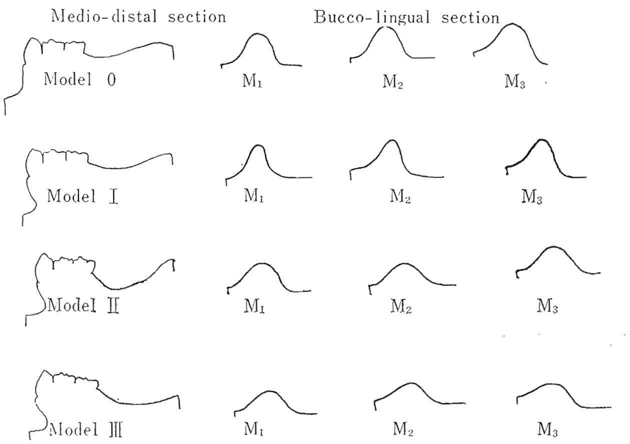

Fig. 1. Medio-distal and bucco-lingual sections of four types simulated mandibular models.

tors were fabricated and these were divided into the following four types: Model 0, minimum loss of residual bone, in clinically good condition; Model I, bucco-lingually narrowed, clinically poor; Model II, with 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 Fig. 1. For each of these four types of simulated models, three types of removable partial denture of unilateral extension saddle-type were designed. These three types of design and construction of dentures were the same as in the previous investigation[1)], as shown in Table 1. The devices for measuring and recording the lateral excursion of the abutment tooth were the same as those reported previously[1)]. Using these devices, the amount of lateral excursion of the abutment tooth were analyzed while a known lateral force was applied on the saddle of the testing dentures. Tooth mobility measurements for each abutment tooth were taken without any denture present, by the use of these devices. Tooth mobility curves were obtained by the direct force application to the objective tooth. To estimate the force dis-

Table 1. Design of the removable partial dentures

Denture	Abutment tooth	Type of retainers
A-type	Mandibular-right 1st premolar	Circumferential-type clasp
	Maudibular-right 2nd premolar	Circumferential-type clasp
B-type	Mandibular-right 1st premolar	Circumferential-type clasp
	Mandibular-right 2nd premolar	T-type bar clasp
C-type	Mandibular-left 1st premolar	Circumferential-type clasp
	Mandibular-right 2nd premolar	Circumferential-type clasp

tribution, the amount of excursion of the abutment tooth due to indirect forces (transmitted from the denture) was compared with the amount of excursion due to direct force applied when the denture was worn. The force distribution to the abutment tooth was determined from the following formula:

Percentage force distribution=

$$\frac{\text{force producing an equivalent excursion of the abutment tooth}}{\text{lateral force applied to the denture}} \times 100$$

Results and Findings

Direct force application

Tooth mobility curves are given by the amount of lateral excursion of abutment tooth when a known direct force is applied to the abutment tooth from buccal to lingual side. These data are shown in Figs. 2, 3, 4, and 5. Tooth mobility curves of abutment tooth on the model 0 and model II were markedly reduced when the partial denture was inserted. However, a slight difference in tooth mobility curves was observed with three types of partial denture inserted in the same simulated model.

Indirect force application

When a known lateral force was applied on the other abutment tooth and denture saddle area, the lateral transmitting forces were estimated as

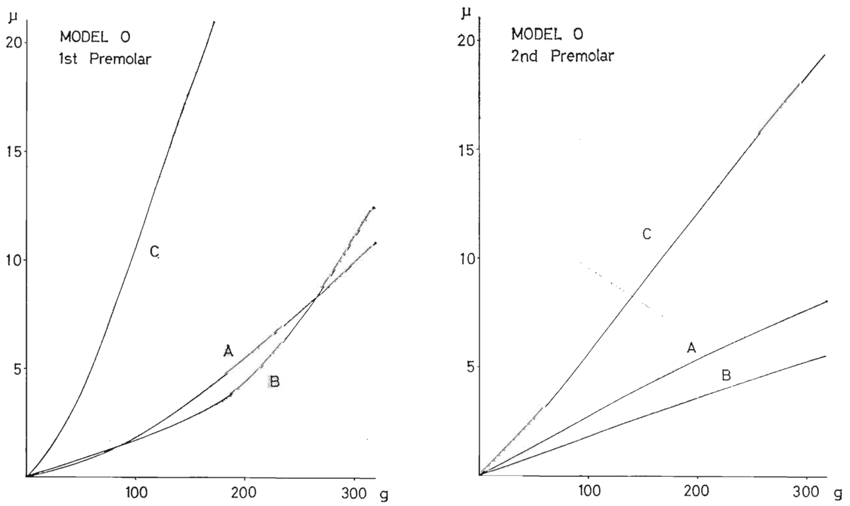

Fig. 2. Tooth mobility curve of first premolar (left) and second premolar (right) in model 0.

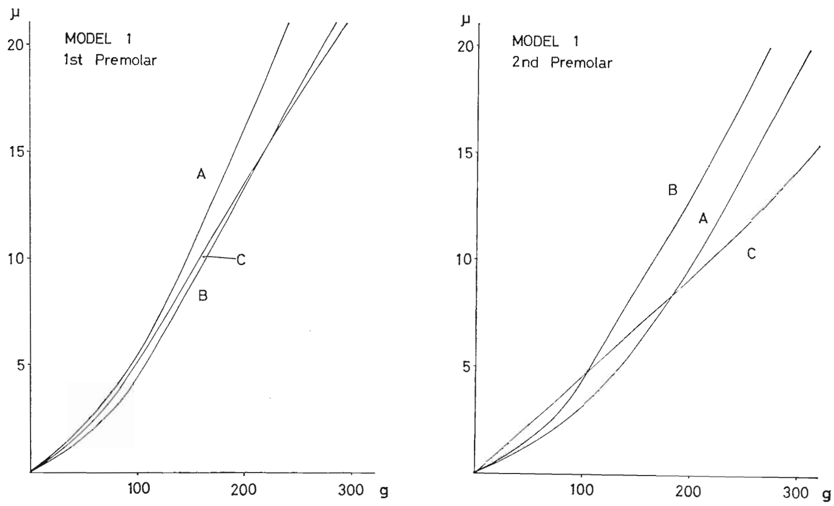

Fig. 3. Tooth mobility curve of first premolar (left) and second premolar (right) in model I.

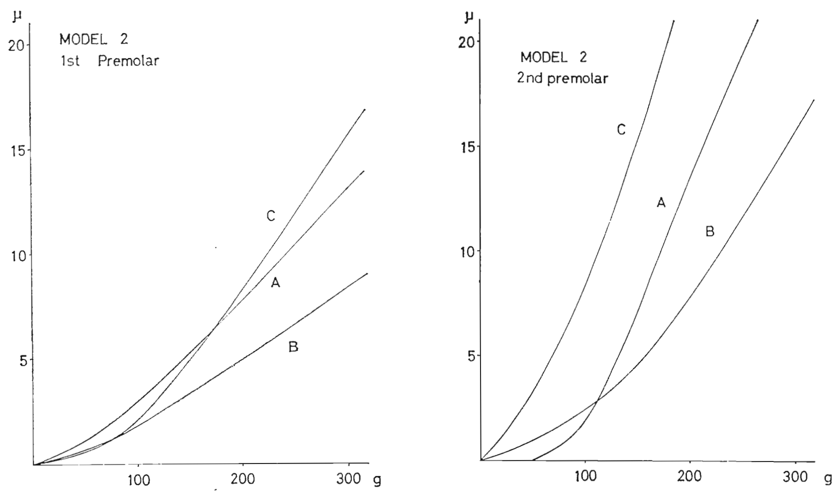

Fig. 4. Tooth mobility curve of first premolar (left) and second premolar (right) in model II.

Table 2. Excursion (in μ) of each abutment tooth during lateral force application of 100, 200 and 300 g

Model	Denture	Abutment tooth	Site of applied force (force in g)											
			1st premolar			2nd premolar			1st molar			2nd molar		
			(100)	(200)	(300)	(100)	(200)	(300)	(100)	(200)	(300)	(100)	(200)	(300)
Type–0	Type-A	4|	...	...	...	+0.4	+0.9	+1.9	+0.8	+1.8	+3.3	+0.6	+1.6	±3.8
		5|	+0.5	+1.1	+2.0	...	...	...	+0.9	+2.3	+4.7	+1.0	+2.6	+4.3
	Type-B	4|	...	...	...	+1.0	+2.4	+4.2	+0.6	+1.6	+2.5	+0.5	+1.0	+1.7
		5|	+0.6	+1.5	+4.4	...	...	...	+0.3	±0.8	±1.5	+0.2	−0.6	−1.2
	Type-C	|4	...	...	...	0	+0.2	+0.2	−0.5	−1.7	−4.0	−0.5	−1.2	−2.4
		5|	+0.4	+1.3	+1.5	...	...	...	+4.4	+10.8	+17.6	+3.9	+9.0	+14.3
Type–I	Type-A	4|	...	...	...	+2.4	+5.3	+7.2	+2.1	+3.9	+4.4	+1.2	±1.8	±2.5
		5|	+3.6	+8.1	+11.8	...	...	...	+2.2	+4.9	+6.4	+2.4	±4.3	±10.3
	Type-B	4|	...	...	...	+2.3	+4.8	+6.9	+1.4	+2.9	+4.9	±0.1	±0.2	±0.4
		5|	+2.8	+6.7	+9.6	...	...	...	+3.8	+6.7	+9.0	+3.7	+6.0	+7.1
	Type-C	|4	...	...	...	±0.2	±0.6	±0.9	−1.0	−2.4	−4.4	−1.2	−3.4	−7.3
		5|	+1.0	+2.2	+3.5	...	...	...	+4.4	+8.7	+17.1	+4.7	+10.4	+17.2
Type–II	Type-A	4|	...	...	...	+1.6	+3.8	+6.0	+1.4	+2.5	+3.1	±0.9	±1.7	±2.4
		5|	+1.2	+2.6	+4.3	...	...	...	+3.8	+19.5	+32.8	+10.0	+23.4	+34.6
	Type-B	4|	...	...	...	+1.5	+3.9	+6.2	+1.2	+3.4	+5.3	+1.0	+2.7	+4.1
		5|	+2.3	+5.2	+8.4	...	...	...	+3.0	+11.8	+23.7	+5.7	+15.3	+26.9
	Type-C	|4	...	...	...	−0.1	−0.4	−0.6	−0.7	−2.9	−6.0	−1.1	−2.9	−5.7
		5|	+1.6	+1.8	±2.1	...	...	...	+12.5	+29.5	+51.2	+16.1	+34.4	+44.8
Type–III	Type-A	4|	...	...	...	+1.6	+4.9	+7.9	+1.5	+3.8	+6.0	+1.4	+2.6	±3.5
		5|	+2.6	+6.5	+10.5	...	...	...	+3.6	+8.9	+16.8	+6.3	+16.8	+27.5
	Type-B	4|	...	...	...	+1.8	+5.1	+8.4	+1.7	+3.9	+5.7	±1.0	±1.8	±2.7
		5|	+2.4	+6.2	+10.4	...	...	...	+7.3	+17.9	+28.7	+8.7	+20.6	+30.6
	Type-C	|4	...	...	...	±0.4	±0.8	±1.0	−0.4	−1.0	−3.3	−1.7	−5.9	−11.2
		5|	−0.1	−0.4	−1.1	...	...	...	+5.4	+12.8	+23.2	+7.9	+19.3	+30.5

Buccal-to-lingual excursion (+), lingual-to-buccal excursion (−).

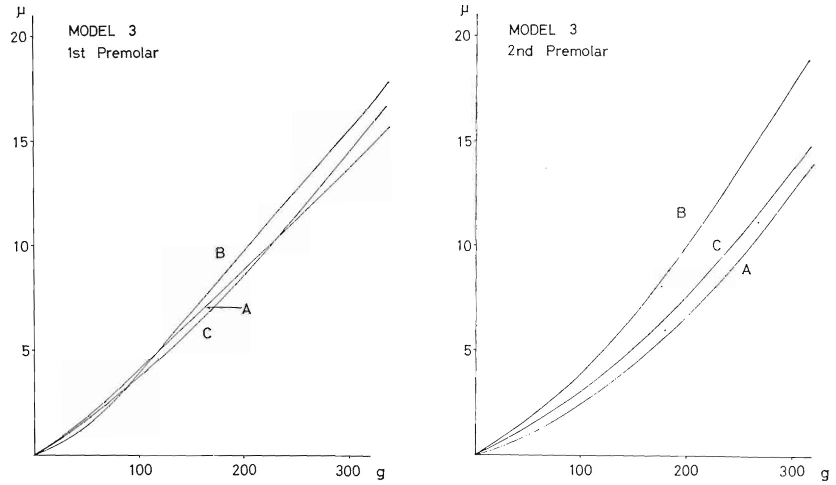

Fig. 5. Tooth mobility curve of first premolar (left) and second premolar (right) in model III.

shown in Table 2. The lateral force was directed from buccal to lingual side, but the direction of the movement of the teeth infinitely depended on the site of force applied. The abutment tooth, indirect retainer in C-type denture, always tended to move in the direction opposite to the applied force. Also the direction of abutment tooth excursion was not always to the lingual side with A-type and B-type dentures in different simulated models.

Force distribution from denture to abutment teeth

These results are shown in Table 3.

Model 0: These are no significant differences in the amount of transmitting force to both abutment teeth according to the direct and indirect retainer of the A-type denture, nor in the location of loading points. With B-type denture, the transmitting force to the abutment tooth of a direct retainer is rather small. With C-type denture, the amount of transmitting force to the abutment of indirect retainer with cross arch design is markedly small, but the amount of transmitting force to the abutment of direct retainer was the highest value among the three types of test dentures.

Model I: With A-type denture, a significant difference is observed in the transmitting force between the direct and indirect retainers in this simulated model. When the location of loading point is to the distal area of the denture saddle, a remarkable increase is found in the transmitting force to the direct retainer. With B-type denture, when the location of

Table 3. Distribution of force from denture (artificial teeth) to each abutment tooth

Model	Abutment tooth	Design of partial denture								
		A-type			B-type			C-type		
		(100)	(200)	(300)	(100)	(200)	(300)	(100)	(200)	(300)
Type–0	1st	49	50	49	36	47	47	8	13	17
	premolar	40	44	53	30	32	34	9	9	11
	2nd	33	42	58	17	20	27	80	90	96
	premolar	36	47	53	9	17	21	72	76	78
Type–I	1st	47	39	28	44	38	35	25	29	30
	premolar	29	21	19	3	3	5	31	37	42
	2nd	73	65	51	92	63	51	94	84	113
	premolar	80	60	68	90	59	44	101	111	113
Type–II	1st	58	44	35	75	76	70	53	59	56
	premolar	42	33	29	62	63	58	69	58	54
	2nd	120	121	113	112	125	126	131	109	103
	premolar	172	136	118	164	147	137	154	120	94
Type–III	1st	41	47	47	57	50	44	14	15	30
	premolar	40	35	29	37	29	26	48	74	82
	2nd	131	121	119	160	152	146	156	144	143
	premolar	191	179	171	182	169	154	206	189	176

Upper values were given while force applied on 1st molar.
Lower values were given while force applied on 2nd molar.

loading point is to the distal area, a remarkable increase of transmitting force to the direct retainer is indicated in this simulated model. Thirty to forty fold significant difference is observed in the transmitting forces between the direct and indirect retainers. With C-type denture, the transmitting force to the indirect retainer, designed on the cross arch is markedly increased in this model I simulator and also a remarkable distribution to the direct retainer is found. The highest value of transmitting force against the abutment tooth was for this type among three types of dentures.

Model II: In this simulated model, the transmitting force to the direct retainer is markedly increased by the case of these three types of partial dentures. These values are almost the same while the loading point is in the first molar area on the saddle, when the loading point tended to the distal area, while the value of the transmitting force to the direct retainer did not indicate a noticeable increase with C-type denture, because the difference in transmitting force between the direct and indirect retainers is smaller than by that in other dentures.

Model III: The transmitting force to the direct retainer is markedly

Table 4. Force distribution from one abutment tooth to another abutment tooth

Model	Abutment tooth	Design of partial denture								
		A-type			B-type			C-type		
		(100)	(200)	(300)	(100)	(200)	(300)	(100)	(200)	(300)
Type–0	1st premolar	27	29	34	62	68	66	0	3	2
	2nd premolar	19	20	24	30	40	82	7	12	10
Type–I	1st premolar	54	49	40	64	52	43	6	8	8
	2nd premolar	109	88	110	77	64	53	21	23	25
Type–II	1st premolar	64	59	55	88	83	79	11	18	15
	2nd premolar	89	54	42	93	78	68	26	15	11
Type–III	1st premolar	45	58	60	59	61	59	14	12	10
	2nd premolar	102	98	89	68	72	69	3	7	13

large in each testing denture on this model III.

The difference of transmitting force between the direct and indirect retainer is extraordinarily small with C-type denture on the model III.

Force distribution from one abutment tooth to another

This result is shown in Table 4. The force transmission between each abutment tooth is in close co-operation, in both A-type and B-type dentures in each simulated model, but in the C-type denture, this relation was not so noticeable. The mutual correlation of transmitting force from one abutment to another and its relation to the residual ridge condition were more intimate in clinically poor ridge.

Discussion

It has been reported in a previous paper that the tooth mobility varies according to difference in the design of removable partial dentures even on the same simulated model. Also, the fulcrum of rotation varies according to the site and amount of force applied as well as to the design of denture on the same simulated model. In order to analyze the denture design in relation to the residual ridge form, the amount of lateral force transmission from the denture to the abutment teeth was examined in the present works by using specially devised simulated mandibular models and previously reported equipments, and the effect of the residual ridge conditions which are related to amount of transmission force from denture to abutment tooth by the wearing of the test denture was observed. In general, when the residual ridge condition tends to be clinically poor, with severe bone resorption in the residual ridge, the amount of transmission forces to the abutment tooth are intimately affected by changing of the denture design. When the residual ridge condition is clinically good, with less bone loss in the residual ridge, changes in denture design greatly affect the transmission force from denture to the abutment tooth.

Henderson and Seward investigated the movement of abutment teeth and stated that abutment positioned farthest from the site of application of force were least affected by such a force. In the present experiment, patterns of the transmission force against the cross arch-designed indirect retainer were greatly affected by the simulator conditions. When the residual ridge is in a rather clinically good condition (less bone loss in the residual ridge), the amount of transmission force to the indirect retainer is quite small, but, in clinically poor residual ridge (excess bone loss), the amount of transmitting force becomes remarkably large. This is why the cross arch-designed indirect retainer is effective for the lateral force, especially when the residual ridge condition is clinically poor. These results indicated that the lateral transmitting force to the second premolar, as the direct retainer, would be highly influenced by small modification of the denture design, when the residual ridge condition is clinically poor. Also the location of the shifting points of the unilateral extension saddle-type denture, as the A or B type design, will be greatly affected by the residual ridge form. The most remarkable results in this experiment are that the modification of denture design will be the largest factor for the changing of lateral force transmission from denture to abutment tooth when the residual ridge condition is clinically good, though when the ridge condition becomes clinically poor, the residual ridge form will be the most intrinsic factor for alteration of the lateral force transmission. The conversion of the direction of transmitting force, between the input and output, suggests a relatively complicated distribution of force with denture constructions and its supporting structures.

Conclusion

This investigation was carried out for the purpose of analyzing the lateral force transmission of the unilateral extension saddle-type removable partial denture, 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 denture for each model were fabricated. The equipments for this investigation were previously reported. Conclusions were as follows:

i) The lateral force transmission to the abutment tooth was highly affected by the condition of residual ridge and denture design. Particularly for the lateral force, the modification of denture design will be a more intrinsic factor for the alteration of load distribution than the condition of residual ridge form, but when the residual ridge form tends to be clinically poor, the ridge condition will be a larger factor than the denture design.

ii) When the condition of residual ridge tends to be clinically poor, with excess bone loss, cross arch-designed indirect retainer withstands the lateral force transmission.

iii) When the condition of the residual ridge is clinically good, unilateral design for the unilateral molar-missing is available. When the condition of residual ridge is clinically poor, the bilateral design, cross-arch location of indirect retainer, is desirable.

Acknowledgement

The authors express their gratitude to Prof. Isamu Nakazawa for his constant interest, guidance, and kind advice in this investigation.

Reference

1) Matsumoto, M., Goto, T., and Tateishi, T.: Evaluation of the residual ridge and denture design in relation to the lateral force distribution to the abutment teeth. Bull. Tokyo Med. Dent. Univ., 19: 211–235, 1972.