Journal of Oral Rehabilitation 1999 **26**; 111–116

Stress distribution and abutment tooth mobility of distal-extension removable partial dentures with different retainers: an *in vivo* study

Y. IGARASHI, A. OGATA, A. KUROIWA & C. H. WANG* *Department of Removable Prosthodontics, Matsumoto Dental College, Nagano, Japan and *School of Dentistry, Kaohsiung Medical College, Kaohsiung, Taiwan*

SUMMARY **Three types of retainers (wrought wire clasp, Aker's cast clasp, and conical crown telescopic retainer) designed for distal-extension removable partial dentures (RPDs) were assessed in two Kennedy class I patients' mouths. The assessment, included the ratio of denture base shearing load and mobility of the terminal abutments when loaded on a free-end RPD occlusal surface. The mean values of denture base shearing ratios of wrought wire clasp, Aker's clasp and conical crown telescope were 60, 42 and 20%, respectively. The abutment mobility of the three types of retainers were all within the 'mobile ability area' except the wrought wire clasp for patient A's right side. The greatest tooth mobility was observed with the wrought wire clasps, followed by Aker's clasp and the conical crown telescopic retainer. From the analysis the following was concluded: (i) different retainers do influence the occlusal load distribution; (ii) the occlusal load distributed to the free-end saddle is closely related to the connecting rigidity of the retainer; (iii) mucosal support has an indispensable role in sharing the occlusal load with various retainers, even the rigid telescopic retainer.**

Introduction

When a removable partial denture (RPD) is considered for restoration of missing posterior teeth in the distal free-end edentulous ridges, the design of the RPD is a problem. The displacements are quite different between the periodontal support tissues of abutments and the residual ridge mucosa (Steiger & Boitel, 1959; Körber, 1974; Boucher & Renner, 1982). When the functional occlusal load is induced on this kind of distal-extension RPD, a rotary movement usually occurs around the fulcrum of the terminal abutments (Boucher & Renner, 1982; McGivney & Castleberry, 1995). This phenomena not only lowers the denture function and causes the patient's discomfort but also traumatizes the supporting tissues of dentures. A good design for a distal-extension RPD should prevent rotary movement in order to protect the supporting tissues.

There have been numerous studies discussing the RPD design for distal-extension appliances, including bench model analysis (Kaires, 1956; Shohet, 1969; Matsumoto & Goto, 1970; Cecconi, Asgar & Dootz, 1971; Taylor, Pflughoeft & McGivney, 1982; Firtell, Grisius & Muncheryan, 1985; Feingold, Grant & Johnson, 1986; Browning, Meadors & Eick, 1986; Ogata, Ishii & Nagare, 1992) and photoelastic stress analysis (Thompson, Kratochvil & Caputo, 1977; Kratochvil & Caputo, 1974; White, 1978; Fisher & McDowell, 1984). These were almost all model analyses, only a few studies (McCartney, 1980; Körber, 1983; Bazirgan & Bates, 1986) were dynamic analyses in the patient's mouth. It is difficult to simulate the viscoelastic properties of periodontal ligament and residual ridge mucosa, only analysing in the mouth can reflect the true conditions. The purposes of this study were to compare the various retainer designs for distal-extension RPD by measuring the denture base shearing load and the abutment tooth mobility in the mouth.

Table 1. Data of two mandibular Kennedy class I subjects

	Sex and age	Right side		Left side	
Subject	(years)	Missing	Detected abutment	Missing	Detected abutment
Patient A	male, 70	#45, 46, 47	#44	#34, 35, 36, 37	#33
Patient B	female, 68	#46, 47	#45	#34, 35, 36, 37	#33

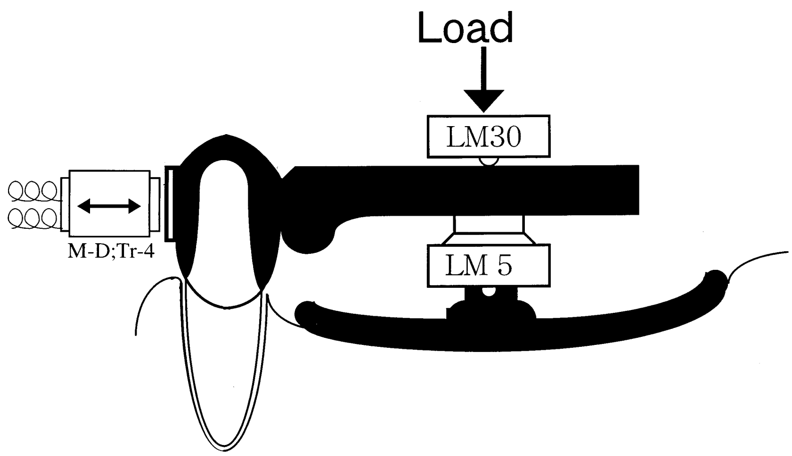

Fig. 1. Special fabricated double denture bases to measure the denture base shearing load of occlusal force.

Materials and methods

Two subjects (patient A and patient B, Table 1) with mandibular Kennedy class I edentulous saddles were analysed after their informed consent. The subjects had no other complications in their stomatognathic system and general health and the periodontal conditions of the abutments were healthy. Three types of retainers were constructed for the analyses, they were wrought wire clasp (W), Aker's clasp with distal rest (C) and the conical crown telescopic retainer (K). All the retainers were constructed to conventional standard procedures and connected with a rigid lingual bar major connector.

One micro-load cell transducer LM30* (size: 12·0 mm in diameter and 4·0 mm in thickness) applied the controlled load of 6 kgf (58·8 N) on the occlusal table. Three electronic devices were installed carefully and precisely in the tested dentures and abutments: one micro-load cell transducer LM5† was put between the two layers of the specially fabricated double denture bases to measure the denture base shearing load of the occlusal force (Fig. 1). Two eddy current inductive micro-contactless displacement transducers‡ (Körber 1976; Igarashi & Ai, 1980; Jentner & Eißler, 1986) were put on the middle third buccal surface of both bilateral terminal abutments to detect the horizontal mesiodistally abutments displacements. One of the experimental denture assemblies is illustrated in Fig. 2. The electronic signals of the above electronic devices were amplified by dynamic strain amplifiers‡, recorded simultaneously by a data

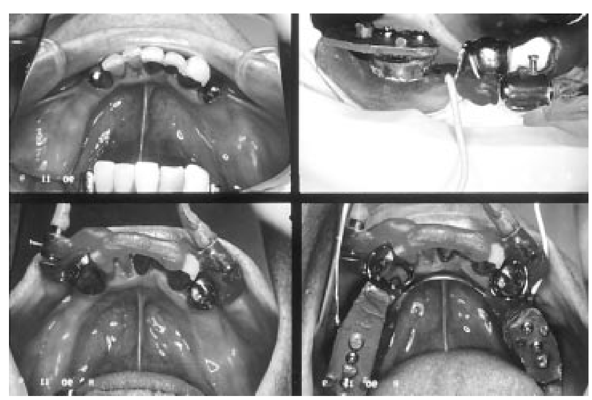

Fig. 2. One of the experimental denture assemblies that was tested.

* LM-30; Kyowa Electronic Instruments Inc., Tokyo, Japan.
† LM-5: Kyowa Electronic Instruments Inc.
‡ Tr 4; Hottinger Baldwin Messtechnik GMBH Co., Darmstadt, Germany.

Table 2. The denture base shearing loads and ratios (unit: kgf)

	Patient A		Patient B		
Retainers	Right side	Left side	Right side	Left side	Mean (%)
W	3·60 (60%)	3·84 (64%)	3·06 (51%)	3·96 (66%)	3·62 60%)
C	3·00 (50%)	2·34 (39%)	1·74 (29%)	3·06 (51%)	2·54 (42%)
K	1·32 (22%)	0·78 (13%)	1·56 (26%)	1·02 (17%)	1·17 (20%)

W, wrought wire clasp; C, Aker's clasp; K, conical crown telescope.

recorder§ and then output to an X–Y recorder¶ to produce the graphs.

Before each experiment, all the transducers were corrected to equalize the unbalanced electronic bridges. Each micro-contactless displacement transducer also measured some digital calipers** for calibrated reference data. The procedure was repeated five times for every situation and the measurements followed the sequence W, C and K. There were 15 min intervals between each retainer test for both patients. After each test, the prosthesis was removed from the subject's mouth, cleansed, and the next tested denture installed in the mouth. The experiments were performed under controlled conditions to prevent electrical noise. When loaded vertically with the micro-load cell transducer LM30 on the central fossa area of the first molar of the occlusal table and after data transfer and calibration, the results of the abutment tooth movement and denture base shearing load were obtained.

Results

The denture base shearing loads and ratios are shown in Table 2. The ratio of shearing load to occlusal load of W ranged from 51 to 66%, and that of C and K were 29 to 51% and 13 to 26%, respectively. The relationships between occlusal load and base shearing load were plotted for both patients (Figs. 3–6). As the occlusal load increased, the denture base shearing load increased gradually, the fastest increase was in W, and the slowest was in K. With a 6 kgf occlusal load, the highest ratio of denture shearing load was in W, followed by C and K.

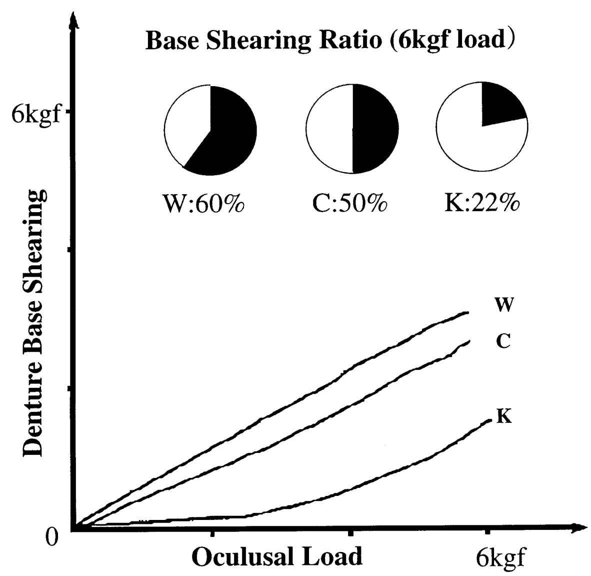

Fig. 3. The relationship between occlusal load and denture base shearing load for patient A's right side. W, wrought wire clasp; C, Aker's cast clasp; K, conical crown telescopic retainer.

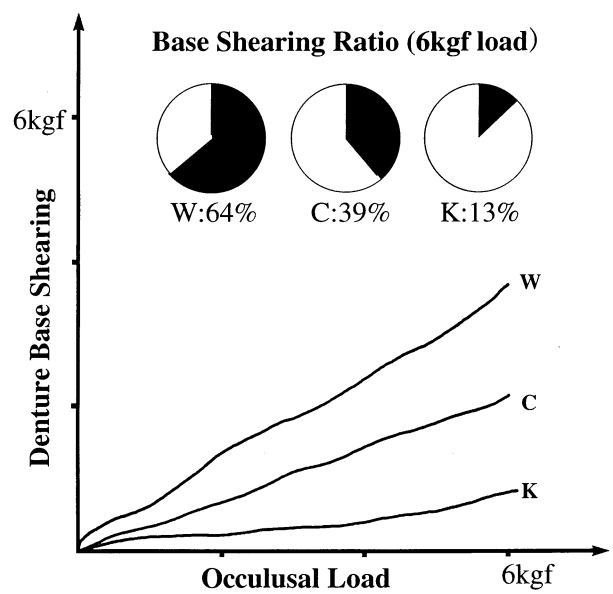

Fig. 4. The relationship between occlusal load and denture base shearing load for patient A's left side. W, wrought wire clasp; C, Aker's cast clasp; K, conical crown telescopic retainer.

§ Nichiden-Sanei Electronic Instruments Inc., Tokyo, Japan.
¶ WX 2311, Graftec Inc., Tokyo, Japan.
** Digimatic 500, Mitsutoyo, Kanagawa, Japan.

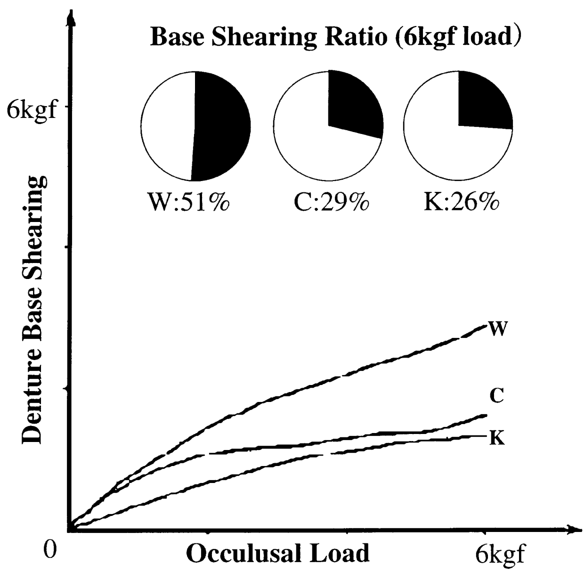

Fig. 5. The relationship between occlusal load and denture base shearing load for patient B's right side. W, wrought wire clasp; C, Aker's cast clasp; K, conical crown telescopic retainer.

The mean and standard deviation of mesiodistal movements of the terminal abutments are listed in Table 3. The positive value was the abutment distal displacement and the negative value was mesial displacement. The results of the ANOVA applied to these movements indicated a statistically significant design effect ($F = 5{\cdot}42$, $P < 0{\cdot}01$). With respect to specific comparisons, statistically very highly significant differences ($P < 0{\cdot}001$) in movement existed between the designs for patient A's left side; between C and K for patient B's left side; and between K and W for patient B's right side. Highly significant statistical differences ($P < 0{\cdot}01$) existed between K and W for patient B's left side; between W and C for patient B's right side; and C and K for patient B's right side. Statistically significant differences ($P < 0{\cdot}05$) existed between K and W for patient A's right side. The abutment movements of W were the largest, and the conical crown telescope were the smallest. Fig. 7 shows the comparisons for the abutments movements.

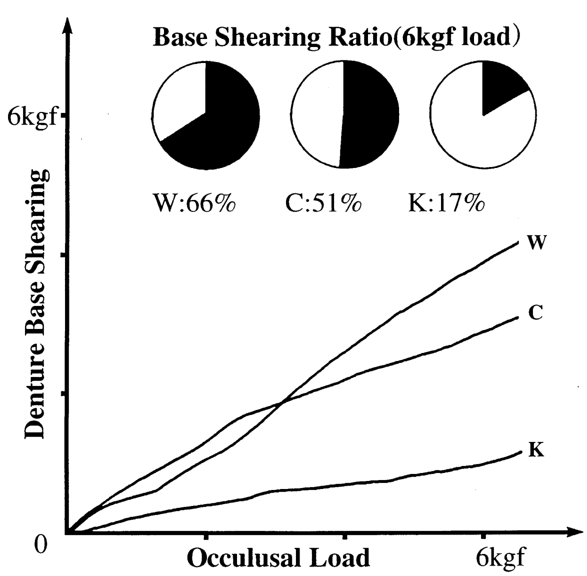

Fig. 6. The relationship between occlusal load and denture base shearing load for patient B's left side. W, wrought wire clasp; C, Aker's cast clasp; K, conical crown telescopic retainer.

Discussion

The ratio of denture base shearing load to total occlusal force is the percentage of occlusal load to transmit to the residual ridge under the denture base. The mean values of denture base shearing ratios of the wrought wire clasp, Aker's clasp and conical crown telescope were 60, 42 and 20%, respectively (Table 2). The studies of Igarashi (1989a,b, 1990) pointed out that the more rigid the connection for the retainer the less denture mobility and vice versa. These observations coincided with those of Briede, Klötzli & Körber (1970) and Körber (1983). The wrought wire clasp is the least rigid of the three retainers, therefore it will have the greatest mobility, and so requires the highest rate of support from mucosa tissues. In contrast, the rigidity of the conical crown telescopic retainer was the highest, and needed the least amount of tissue support. From this study, the denture base shearing load measured from the conical crown telescopic retainer RPDs were low and regular with very small deviations. When considering of the maintenance factors of the residual ridge for free-end saddle RPDs (Häupl & Riedel, 1966; Singer & Schon, 1968), it seemed that the conical crown telescope is better for ridge maintenance. Less mobility infers a more stable occlusion during occlusal functioning, and this contributes to the maintenance of the temporomandibular joint in the normal relationship and to reducing the possibility of discomfort (Igarashi, 1987).

In contrast to the denture base shearing load, stress to the abutments increased from 40% with wrought wire clasps to 58% with Aker's clasps and 80% with

Table 3. The abutments movements of various retainers (unit: μm)

Patient-abutment	Patient A		Patient B	
Retainer	Right first premolar (#44)	Left canine (#33)	Right second premolar (#45)	Left canine (#33)
W	363·5 ± 13·2	−32·9* ± 8·0	−67·9 ± 7·9	89·7 ± 8·1
C	162·0 ± 14·0	−43·1 ± 8·4	−80·6 ± 11·5	64·5 ± 8·1
K	76·5 ± 8·2	−46·2 ± 7·1	−50·8 ± 3·6	38·9 ± 9·0

W: wrought wire clasp, C: Aker's clasp, K: conical crown telescope.
* Positive: distal displacement, negative: mesial displacement.

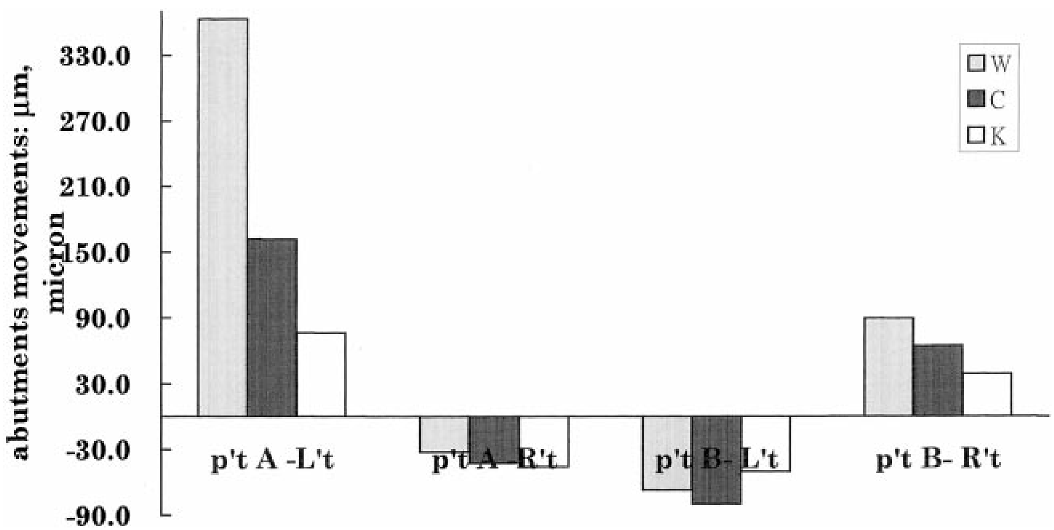

Fig. 7. The comparisons of abutments movements for various retainers. W, wrought wire clasp; C, Aker's cast clasp; K, conical crown telescopic retainer.

conical crown telescopic retainers. Clinical experience with the conical crown telescope supports these facts. In the study of Igarashi (1984) crown and root fractures were more prevalent on devitalized abutments than vital ones. Stress to the abutment's periodontal tissue was assessed as the abutment tooth mobility. Statistically significant differences existed between the three types of retainers, the abutment movements of various retainers also corresponded with the connecting rigidity of the retainers (Table 3 and Fig. 7). The better the connecting rigidity of the RPD retainer the less abutment mobility, so as expected the greatest tooth movement was observed with the wrought wire clasps.

According to the studies of Christidou, Osborne & Chamberlain (1973) and Igarashi (1982), the directions of the abutment movements of free-end RPD are related to the mesiodistal inclination contour of the edentulous residual ridge. On the flat form ridge the terminal abutment displaced distally, on the distal ascending inclined ridge the terminal abutment displaced mesially. The more important benefit to clinical practice is not the displacement direction, whether distally or mesially, but the amount of tooth movement and whether it is confined within the limit of physiologic tooth mobility, attention to which was first drawn by Mühlemann & Rateischack (1963). Körber (1976) and Igarashi & Ai (1980) advocated two-dimensional physiologic tooth mobility as the 'mobile ability area' of the tooth. The abutments movements of this study were confined to the range of the 'mobile ability area'; only patient A's right first premolar with the wrought wire clasp was beyond the mobile ability area.

This study comprised two patients and four distal free-end situations and so clearly the discussion and observations are limited by the sample size. However, the results coincided with clinical experience of the conical crown telescope over a period of several years (Igarashi & Goto, 1996).

References

Bazirgan, M. & Bates, J. (1986) Preliminary study of a method of measuring removable partial denture abutment tooth movement in vitro and in vivo. *Journal of Prosthetic Dentistry*, **56,** 204.

Boucher, L.J. & Renner, R.P. (1982) *Treatment of Partially Edentulous Patients*, 1st edn, 5. C.V. Mosby Inc, New York.

Briede, C., Klötzli, A. & Körber, E. (1970) Untersuchungen zur problematik an totalen und partiellen prothesen. *Deutsche Zahnärtzliche Zeitschrift*, **25,** 793 (in German).

Browning, J.D., Meadors, L.W. & Eick, J.D. (1986) Movement of three removable partial denture clasp assemblies under occlusal loading. *Journal of Prosthetic Dentistry*, **55,** 69.

Cecconi, B.T., Asgar, K. & Dootz, E. (1971) The effect of partial denture clasp design on abutment tooth movement. *Journal of Prosthetic Dentistry*, **25,** 44.

Christidou, L., Osborne, J. & Chamberlain, J.B. (1973) The effects of partial denture design on the mobility of abutment teeth. *British Dental Journal*, **135,** 9.

Feingold, G.M., Grant, A.A. & Johnson, W. (1986) The effect of partial denture design on abutment tooth and saddle movement. *Journal of Oral Rehabilitation*, **13,** 549.

Firtell, D.N., Grisius, R.J. & Muncheryan, A.M. (1985) Reaction of the anterior abutment of a Kennedy class II removable partial denture to various clasp arm designs: an *in vitro* study. *Journal of Prosthetic Dentistry*, **53,** 77.

Fisher, R.L. & McDowell, G.C. (1984) Removable partial denture design and potential stress to the periodontium. *Journal of Periodontics and Restorative Dentistry*, **1,** 35.

Häupl, K. & Riedel, H. (1966) *Zahne und Zahnhalteapparat, in Spezielle Pathologische Anatomie*, Bd I, p. 489, Springer-Verlag, Berlin.

Igarashi, Y. (1982) Free-end saddle partial denture rigidly supported by the abutments. Part 1: functional stress of the abutments. *Journal of Japan Prosthodontic Society*, **26,** 1014 (in Japanese).

Igarashi, Y. (1984) Free-end saddle partial denture rigidly supported by the abutments. Part 3: follow-up study on the dentures. *Journal of Japan Prosthodontic Society*, **28,** 1134 (in Japanese).

Igarashi, Y. (1987) Restoration of the supporting zone of the mandible in partial dentate mouth. Part 5: supporting ability of free end saddle RPD's. *Journal of Showa University Dental*, **4,** 195 (in Japanese).

Igarashi, Y. (1989a) Analysis of the denture dynamics in RPD's. part 1: methods for analyzing the denture dynamics of free-end saddle. *Journal of Japan Prosthodontic Society*, **33,** 369 (in Japanese).

Igarashi, Y. (1989b) Analysis of the denture dynamics in RPD's. part 2: influence of retainers on the dynamics of free-end saddle. *Journal of Japan Prosthodontic Society*, **34,** 128 (in Japanese).

Igarashi, Y. (1990) The connecting rigidity between abutment teeth and retainers in RPD's. *Journal of Japan Prosthodontic Society*, **34,** 1162 (in Japanese).

Igarashi, Y. & Ai, M. (1980) Observation of the tooth support dynamics. Part I: non-contact sensor system. *Journal of Japan Prosthodontic Society*, **24,** 457 (in Japanese).

Igarashi, Y. & Goto, T. (1996) Ten-year follow-up study of conical crown-retained dentures. *International Journal of Prosthodontics*, **10,** 149.

Jentner, W. & Eißler, W.W. (1986) Noncontacting displacement transducers locate and quantify defects on magnets. *Reports in Applied Measurement*, **2,** 15.

Kaires, A.K. (1956) Effect of partial denture design on bilateral force distribution. *Journal of Prosthetic Dentistry*, **12,** 526.

Körber, K.H. (1974) *Konuskronen-Teleskope*, 4 aufl. p. 24, Alfred Huthig Verlag GmbH, Heidelberg (in German).

Körber, K.H. (1976) Berührungslos-elektronisches verfahren zur messung der zahnbeweglichleit. *Z W R*, **85,** 927 (in German).

Körber, K.H. (1983) Dynamischer mechanismus von parodontiumund gew ebsstrukturen unter herausnehmbarem zahnersatz. *Deutsche Zahnärtzliche Zeitschrift*, **11,** 975 (in German).

Kratochvil, F.J. & Caputo, A.A. (1974) Photoelastic analysis of presure on teeth and bone supporting removable partial dentures. *Journal of Prosthetic Dentistry*, **32,** 52.

Matsumoto, M. & Goto, T. (1970) An experimental investigation in design and force distribution with unilateral mandibular distal extension removable partial dentures. *Bulletin of the Tokyo Medical Dental University*, **17,** 113.

McCartney, J.W. (1980) Motion vector analysis of an abutment for a distal-extension removable partial denture: a pilot study. *Journal of Prosthetic Dentistry*, **43,** 15.

McGivney, G.P. & Castleberry, D.J. (1995) *McCracken's Removable Partial Prosthodontics*, 9th edn, pp. 166, 331. C.V. Mosby Inc., New York.

Mühlemann, H.R. & Rateischack, K.H. (1963) Mechaniscke und elektronische zahnbeweglichkeitmessungen. *Deutsche Zahnärtzliche Zeitschrift*, **18,** 1352 (in German).

Ogata, K., Ishii, A. & Nagare, I. (1992) Longitudinal study on torque transmitted from a denture base to abutment tooth of a distal extension removable partial denture with circumferential clasps. *Journal of Oral Rehabilitation*, **19,** 245.

Shohet, H. (1969) Relative magnitudes of stress on abutment teeth with different retainers. *Journal of Prosthetic Dentistry*, **21,** 267.

Singer, F. & Schon, F. (1968) *Partial Dentures*, 1st edn, 16. Quintessence Publishing Co, Chicago, IL.

Steiger, A.A. & Boitel, R.H. (1959) *Precision Work for Partial Dentures*. Stebo, Zurich.

Taylor, D.T., Pflughoeft, F.A. & McGivney, G.P. (1982) Effect of two clasping assemblies on arch integrity as modified by base adaptation. *Journal of Prosthetic Dentistry*, **47,** 120.

Thompson, W.D., Kratochvil, F.J. & Caputo, A.A. (1977) Evaluation of photoelastic stress patterns produced by various designs of bilateral extension removable partial dentures. *Journal of Prosthetic Dentistry*, **38,** 261.

White, J.T. (1978) Visualization of stress and strain related to removable partial denture abutments. *Journal of Prosthetic Dentistry*, **40,** 143.

Correspondence: Dr Chau-Hsiang Wang, School of Dentistry, Kaohsiung Medical College, 100, Shih-Chen 1st Road, Kaohsiung, 80708 Taiwan.