On the clinical deformation of maxillary complete dentures

Influence of denture-base design and shape of denture-bearing tissue

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This paper aimed to study the influence of denture base design and the shape of the denture-supporting area on the functional deformation of maxillary complete dentures. Six strain-gauged duplicate maxillary dentures were made for the study of two test subjects with different shapes of the palatal vault. Each subject was supplied with two polymethyl methacrylate dentures, one with a 1-mm-thick palatal base and the other 2 mm thick. A third denture was constructed with a cobalt–chromium base. The functional loading tests included maximum biting and the chewing of the food test samples. An analysis based on chewing time and total number of chewing cycles per test piece was also made. The results showed that surface straining is highly complex at the anterior part of the maxillary dentures constructed from polymethyl methacrylate and that increasing the denture thickness per se might not be accompanied by a reduction of strain. The results also suggest that high thrust to the supporting tissue is produced with high palatal vault dentures made in polymethyl methacrylate. The study proposes that cobalt–chromium bases may be used in maxillary dentures to reduce functional deformation and thrust to the supporting tissues at the anterior part of the maxilla.
□ *Physical properties; prosthetics*

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Several longitudinal and clinical studies of complete denture wearers have shown a high prevalence of oral lesions associated with the use of maxillary complete dentures (1–6).

Pendleton & Glupker (7), Pendleton (8), Östlund (4), and Newton (9) attributed these reactions to high stress levels and unequal distribution of the functional stress at the interface between the denture base and the oral mucosa. Studies of the reduction of residual ridges (10, 11) indicated that a prosthetic factor, such as the type of denture base, is a possible co-factor, together with functional, metabolic, and anatomic factors as possible etiologic conditions.

In a previous study Glantz et al. (12) investigated the influence of tissue conditioners on the clinical deformation pattern of maxillary complete dentures. It was observed in that study that the thickness of the tissue conditioning material had the greatest single influence on the deformation pattern and the functional efficiency of the acrylic dentures studied. They also concluded that the anatomic shape of the edentulous maxillae may have a bearing on the type and magnitude of the functional stresses that appear in the denture.

To analyze further these factors, it was considered worthwhile to evaluate the influence of denture base design and the shape of the denture-bearing tissue on the clinical deformation of maxillary complete dentures.

Materials and methods

From the records of the School of Dentistry, Malmö, two female complete denture wearers, 57 and 74 years of age, were selected as test persons. They have been

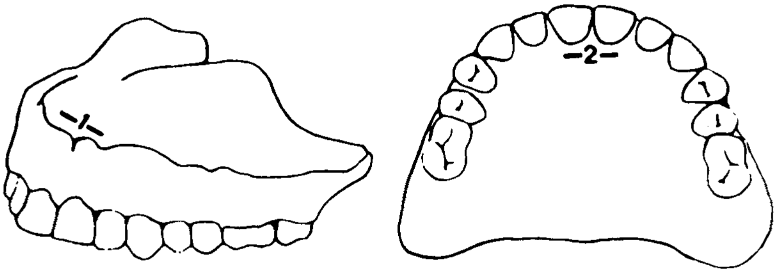

Fig. 1. Diagram of palatal, mucosal, and vestibular surfaces of maxillary complete denture to show strain-gauge number and location.

described in a previous study by Glantz et al. (12). The test persons had been wearing complete maxillary and mandibular dentures successfully for several years, and their complete denture treatment had been revised 6 months before the start of this study.

The shapes of the denture-bearing maxillae differed considerably between the two test persons. Test subject A had a shallow palatal vault, whereas subject B had a deep one; otherwise the patients had normal intermaxillary relations and claimed to be in good general health.

By means of standard clinical and laboratory procedures, each patient was supplied with two maxillary dentures duplicated in an autopolymerized material, type Acron-Hi (Austenal Dental, Inc., Chicago, Ill., USA). One duplicate denture was produced with a 1-mm-thick palatal base, and the other with a 2-mm-palatal base. The base and the teeth of the dentures were processed in the duplicate material, which was handled in accordance with the manufacturer's instructions.

A third denture was constructed for each patient, using a cobalt–chromium alloy (Vitallium, Austenal Dental Inc.) as base material for the denture, which had an overall palatal thickness of 0.6–0.8 mm. The teeth and the labial and buccal flanges were processed in the Acron-Hi Polymer. The polymer was retained to the metal plate mechanically.

With the methods described by Glantz & Stafford (13, 14) two linear strain gauges, type EA-06-062AQ-350 (Micro-Measurements, Romulus, Mich., USA), were attached to the denture bases in the positions shown in Fig. 1. No. 1 gauges, which were placed on the tissue surfaces of all the dentures in the region of the incisal foramen, were positioned to measure lateral strain. No. 2 gauges were placed on the oral surfaces parallel to and immediately opposite no. 1 gauges.

The gauges were attached to the duplicate dentures with a resin cement, type M-Bond 200 (Micro-Measurements). The cemented gauges were coated with a silicone–rubber material, type Dow Corning Coaded 3140 RTV (Dow Corning Corp., Midland, Mich., USA), for isolation purposes.

The gauges were connected to a signal conditioner and amplifier, type 2100 (Vishay Instruments, Malvern, Pa., USA), and to a UV-recorder, type SE 6150 MK 11 (S.W. Labs Ltd., Feltham, Middlesex, U.K.), previously described by Glantz & Stafford (14). The strain-gauged dentures were placed in the mouth of the test persons and were conditioned and calibrated as has been described in detail by Glantz & Stafford (13).

The following clinical experiments were performed on each test person using the duplicated experimental dentures described above: a) The test person was asked to bite maximally 10 times, each bite lasting for about 2 sec and separated by a 5-sec relaxation period; and b) Each test subject was asked to chew a sample of bread and apple; each chewing food sample was separated by a 5-min relaxation period.

The bread sample consisted of fresh crust-free cubes (20 × 20 × 20 mm) of French bread. The apple samples consisted of peeled cubes (20 × 20 × 20 mm) of Golden Delicious apples.

Ten consecutive chewing strokes were made for calculation of strain for each food sample. The total number of chewing strokes and the time required until swallowing was also recorded.

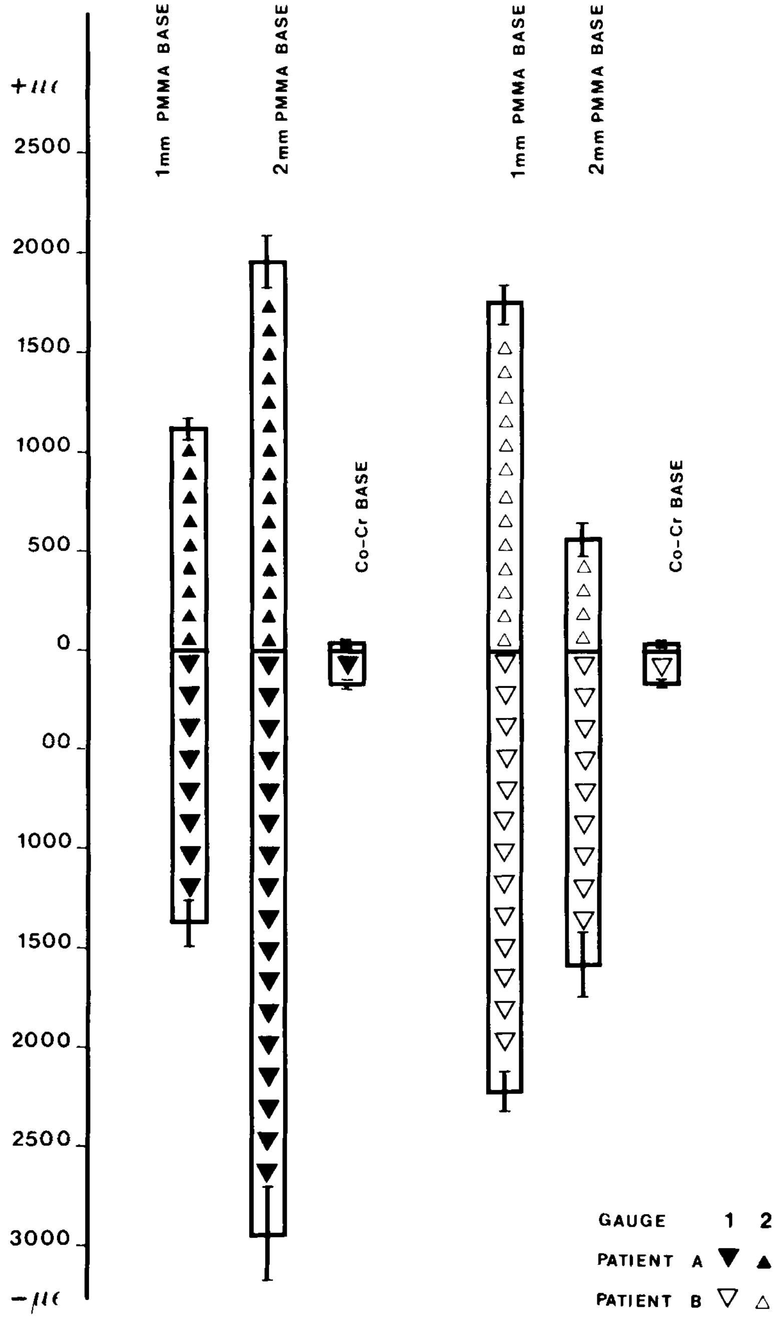

Fig. 2. Strain (true με) values in complete maxillary dentures of 1-mm- and 2-mm-thick palatal bases of polymethyl methacrylate and Co–Cr bases of two test persons during maximum bites. (Positive values denote strain in tension, and negative values denote strain in compression.)

Results

The strain values obtained for the two test persons and the three sets of dentures during maximum bites are illustrated in Fig. 2. Figs. 3 and 4 give the corresponding strain values during the chewing of bread and apple.

Examination of the recorded strain values

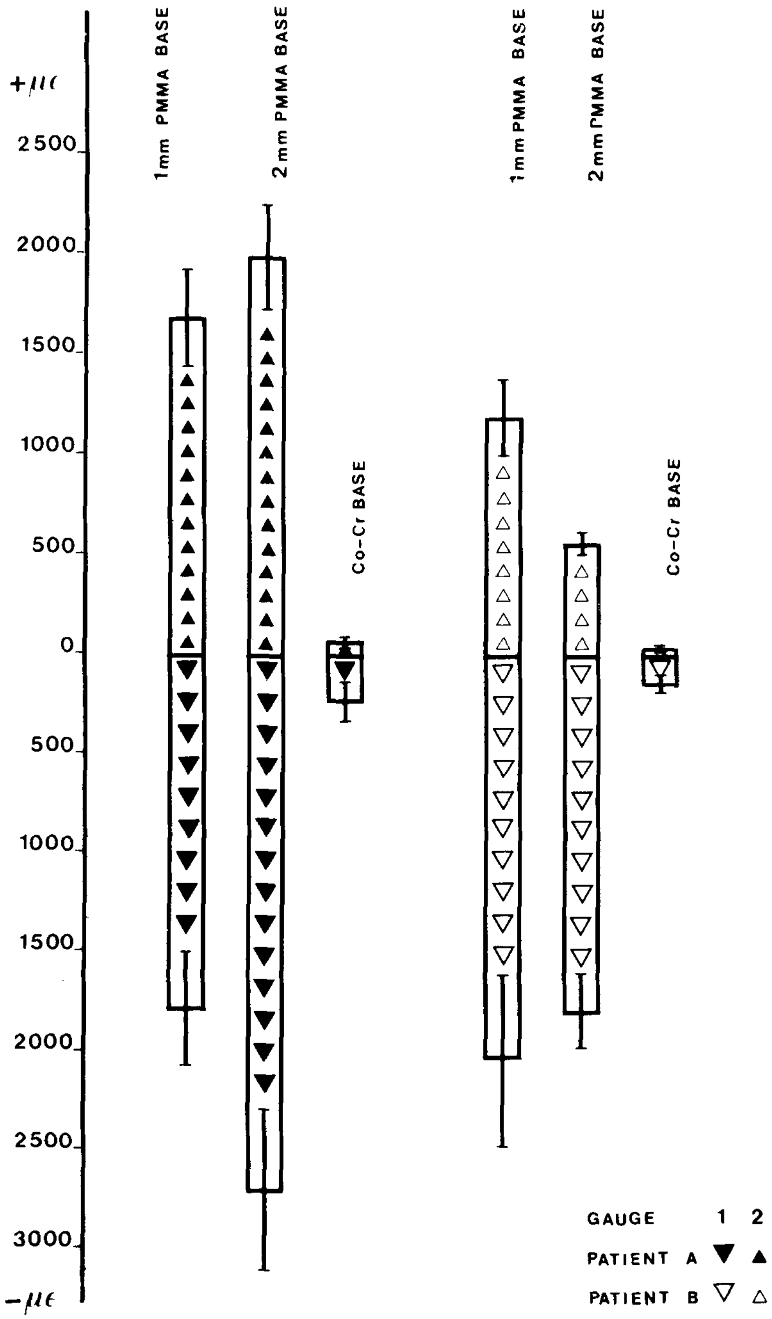

Fig. 3. Strain (true με) values in complete maxillary dentures of 1-mm- and 2-mm-thick palatal bases of polymethyl methacrylate and Co–Cr bases of two test persons during chewing of bread. (Positive values denote strain in tension, and negative values denote strain in compression.)

shows that each denture has its individual deformation pattern, which is relatively consistent for the three clinical loading situations. Furthermore, higher strain in compression was recorded by gauge 1 than for strain in tension by gauge 2.

Examination of the strain values recorded by patient A, with the acrylic dentures,

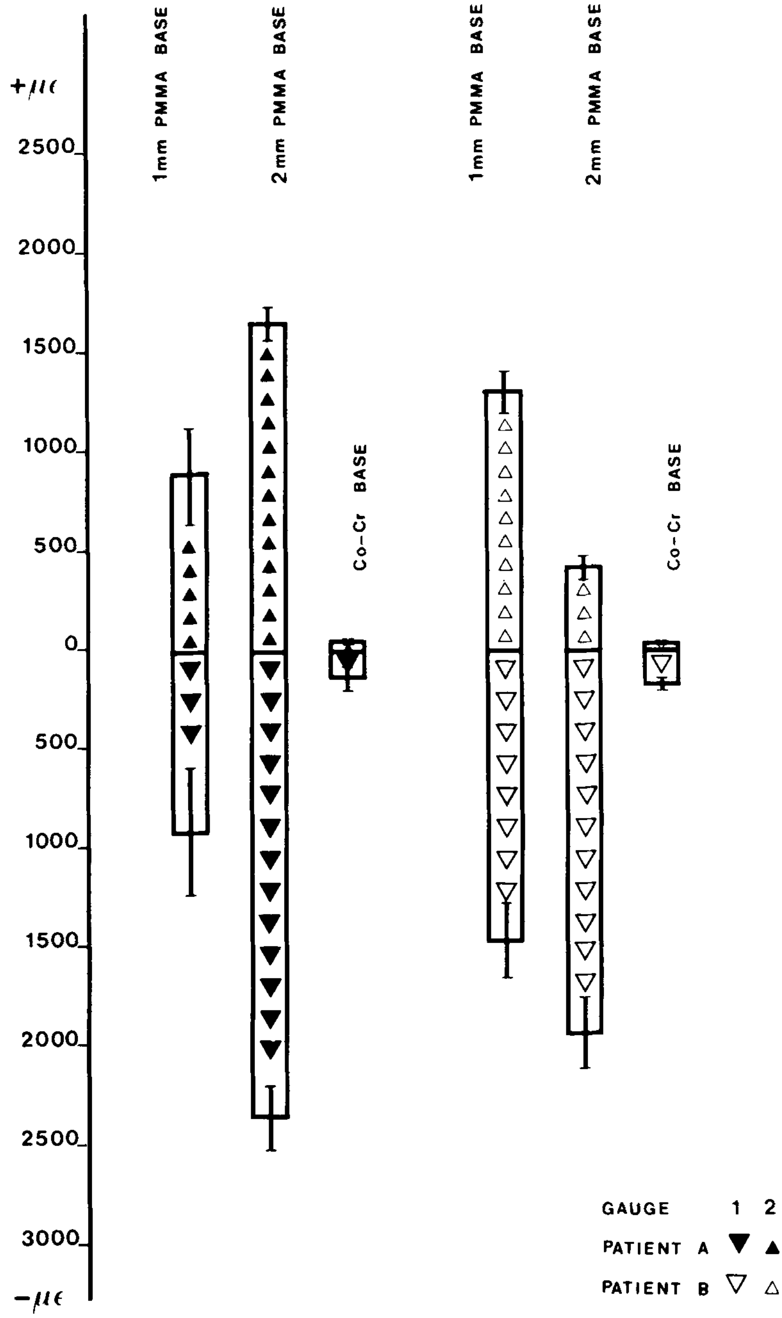

Fig. 4. Strain (true με) values in complete maxillary dentures of 1-mm- and 2-mm-thick palatal bases of polymethyl methacrylate and Co-Cr bases of two test persons during chewing of apple. (Positive values denote strain in tension, and negative values denote strain in compression.)

demonstrated that there is an increase in the magnitude of the strain values in the 2-mm-thick denture as compared with the 1-mm-thick denture in both gauges during the three clinical situations—that is, maximum biting, and chewing of bread and of apple. This might be related to the fact that the biting and chewing forces are not distributed uni-

Table 1. Calculated thrust (α) and bending (β) moments (true $\mu\varepsilon$) in the area of the incisal foramen in complete maxillary dentures of 1-mm- and 2-mm-thick palatal bases of polymethyl methacrylate and Co–Cr bases of two test persons during maximum bites, and chewing of bread and of apple

	Patient A		Patient B	
	α	β	α	β
Maximum bite				
1 mm thick	−134.35	1256.55	−231.80	1981.80
2 mm thick	−486.20	2454.70	−508.60	1071.00
Co–Cr base	−73.75	108.05	−63.90	79.50
Chewing of bread				
1 mm thick	−59.79	1744.90	−425.10	1615.80
2 mm thick	−369.70	2353.00	−624.70	1188.90
Co–Cr base	−99.60	145.90	−68.90	81.10
Chewing of apple				
1 mm thick	−44.15	928.55	−87.30	1385.45
2 mm thick	−317.10	2003.55	−761.50	1181.70
Co–Cr base	−51.25	87.35	−32.40	48.00

formly in the denture base owing to the flexibility of the 1-mm-thick denture as compared with the 2-mm-thick one, and thus a shift of the principal strain might have taken place (15).

In patient B (with the high palatal vault), although there was a reduction of the strain in tension recorded by gauge 2 when the thickness of the denture was increased from the 1-mm- to the 2-mm-thick denture, the level of the strain in compression recorded by gauge 1 varied greatly in the three loading conditions.

The deformation pattern, as given by the straining values on the two sides of the cobalt–chromium-based denture, was comparable and consistent for both patients. Further, all functional strain levels were at a much lower level than for the polymethyl methacrylate denture bases. To evaluate the uniformity of deformation on both sides of the dentures, the mean thrust (α) and bending (β) moments were calculated in accordance with formulae given by Glantz & Stafford (14) and Stafford et al. (16)

$$\alpha = \frac{\varepsilon_1 + \varepsilon_2}{2}$$

$$\beta = \frac{\varepsilon_1 - \varepsilon_2}{2}$$

where ε_1 and ε_2 denote the amount of strain

Table 2. Chewing times (sec) and frequencies while chewing bread or apple (total number of chewing cycles/test piece) with 1-mm- and 2-mm-thick acrylic base and Co–Cr base of maxillary complete dentures

	Bread				Apple			
	Patient A		Patient B		Patient A		Patient B	
	Chewing time (sec)	No. of chews	Chewing time (sec)	No. of chews	Chewing time (sec)	No. of chews	Chewing time (sec)	No. of chews
1-mm-thick acrylic base	44	53	43	45	48	66	52	57
2-mm-thick acrylic base	45	52	41	41	35	48	47	52
Co–Cr base	36	41	39	38	33	42	40	46

recorded by the oral and mucosal gauges, respectively, as given in Table 1.

Examination of the results shows that the thrust values increased when the thickness of the acrylic dentures increased from 1 mm to 2 mm and that the thrust values for patient B were greater than those for the dentures worn by patient A. Further examination of the results in Table 1 shows that both the thrust and the bending moments are much higher in the polymer bases than in the metallic ones.

The chewing performance with regard to the chewing time and number of chewing cycles is given in Table 2. As can be seen, the metal base dentures recorded less chewing strokes and time than the polymethyl methacrylate one.

Discussion

In discussing the results of strain gauge measurements in the oral cavity one has to bear in mind the complex nature of this biomechanical environment and the associated variations (13, 14, 17). Apart from such factors as the denture base thickness and material and the morphologic anatomy of the denture base foundation—the objective of the present study—further variations include the muscular power of the test subjects, the nature of the soft tissue and its displaceability, the location of the gauges, the stability of the denture bases, the form of the teeth and their position in relation to the supporting ridges (18, 19), and the variation of the food bolus position during chewing (20–22). This last factor is particularly noticeable in this study, in which a relatively high degree of scatter, shown as high standard deviation values, was occasionally recorded during the experimental chewing.

From a strictly biomechanical point of view, the results of this study indicate that surface straining is highly complex at the anterior part of the maxillary dentures constructed of polymethyl methacrylate and that increasing the denture thickness per se might not be accompanied by a reduction of strain. This is particularly true for the shallow palatal vault bases. This finding supports the results presented by Morris et al. (23), who showed that with shallow bases there was an increase in fracture energy for triple-thickness base almost twice that of single- or double-thickness base. Further, the results of this study indicate that the morphology of the edentulous maxilla greatly influences the manner of deformation of the denture base at the anterior palatal part, an area known to deform most in maxillary dentures (18).

Studying flexible denture base materials, Koivumaa (24) pointed out that load distribution on the supporting tissue is not uniform. The evaluation of the uniformity of deformation on both sides of the acrylic denture bases, as given by thrust and bending moments in the anterior palatal part in this study, indicates that in deep palatal vault bases more thrust, and thus more local stress concentration, is imposed on that area. This finding confirms the clinical view that a high palatal vault is less favorable for successful maxillary complete dentures.

On the basis of this study it can be proposed that cobalt–chromium bases may be used in maxillary dentures, specially for those with a high palatal vault, to reduce functional deformation and thrust when considering the tendency of mucosal inflammatory reactions and bone resorption frequently observed among complete denture wearers.

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