On functional strain in fixed and removable partial dentures

An experimental in vivo study

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Three rosette strain gauges were attached to a fixed bilateral cantilevered crossarch maxillary bridge and one linear strain gauge to an attachment-retained removable partial denture (RPD), to study the functional deformation pattern in this combined reconstruction. The deformation under clinical conditions at maximum habitual biting and at maximum unilateral loading was very complex, with both elongation and contraction in different parts of the fixed reconstruction. Even though this complexity in the functional deformation was found both with and without the RPD incorporated, the RPD seemed to provide a more even and favorable distribution of the masticatory forces in the fixed reconstruction. □ *Dental materials; dental prosthesis design; denture, partial, fixed; denture, partial, removable; in vivo deformation*

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In partially edentulous jaws the combination of fixed and removable partial dentures is a common form of therapy. Patients who have lost posterior teeth may be helped by partial bridgework attached to osseointegrated implants, but in most cases a removable partial denture (RPD) in combination with a fixed bridge is a good solution. Extended cantilever-fixed reconstructions have been reported to have a worse prognosis than conventional end abutment bridges (1) because of high and unfavorable stresses and deformations around the last abutment tooth (2, 3). If an attachment for an RPD is placed in a cantilever pontic, even more critical deformation around the last abutment could be expected. Such rehabilitations may in the future also be used in implant-supported bridges. The magnitude, duration, and frequency of occlusal forces during natural function such as chewing, swallowing, and biting vary between different people. Voluntary maximum biting forces are usually limited by pain or discomfort but not when they are distributed among several posterior teeth (4).

In the direction of the long axis of the supporting teeth, however, lower chewing or biting forces are used on posterior cantilevered reconstructions than at end abutment regions (5). A previous investigation, based on model experiments, showed that an RPD connected to a fixed reconstruction influenced the deformation patterns in the fixed bridge, making them less extensive and less complex than without the RPD (6). Model experiments have their limitations, and it is difficult to know how valid the results are in clinical situations.

The aim of this investigation was to study the functional deformation in a fixed partial denture (FPD) in combination with an RPD. An 11-unit FPD with an attached RPD was used, and at various points strain gauges were attached to the FPD and also to the RPD. The construction was studied in a specified bite program, and the deformations were recorded.

Materials and methods

A 29-year-old man, in good general and oral health, who was in need of a maxillary prosthetic reconstruction was chosen for this study. The remaining teeth in the upper jaw were the right and left canine, right lateral incisor, and the central incisors. The canine on the left side was orthodontically moved to position 24. All the remaining maxillary teeth were in good periodontal condition, with no or minor reductions of the periodontal bone support, had no fillings, and showed no signs of caries. In the mandible only the first and third molars bilaterally were missing. The five maxillary teeth were prepared for crown therapy in accordance with general principles (7). A full-arch silicone impression (President, light and heavy body) was taken in a rigid custom impression tray of cold-cured acrylic covering the prepared teeth, the distal edentulous part of the alveolar ridges, and the palate. An alginate impression was taken of the lower jaw, using a standard impression tray. The impressions were poured immediately in Vel-Mix stone (Kerr Europe, Scafati). All the materials used were handled in accordance with the manufacturers' instructions.

The models were mounted in a Dentatus ARL articulator after a clinical jaw registration had been performed. An 11-unit FPD was manufactured in high precious gold alloy (C-guld, J. Sjöding & Co., Solna, Sweden) with two cantilever pontics on each side. A cobalt-chromium RPD was connected to the bridgework with two precision attachments (McCollum, Cèndre Metaux, Switzerland) mounted bilaterally in the distal cantilever pontics (Fig. 1). The fixed and removable prosthetic reconstructions were tried in the mouth and found to fit satisfactorily. The occlusion was adjusted intraorally to stable occlusal contacts of the whole combined prosthetic reconstruction to the opposing dentition in the mandible. No supracontacts in occlusion were thereafter noted.

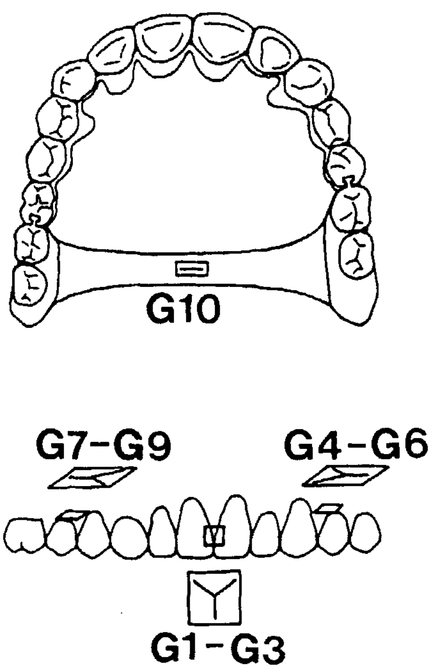

Fig. 1. An 11-unit fixed partial denture with a chromium cobalt skeletal removable partial denture. At marked sites strain gauges are glued on the bridge and the bar.

Strain gauges were attached to the fixed and removable partial dentures as described in detail in the laboratory study of deformation by Randow & Dérand (6). In this study the same reconstruction was used to study the clinical deformation.

The patient was asked to perform maximum habitual biting on the FPD with and without the RPD. In addition, maximum biting was performed on a wooden stick positioned over the distal cantilever part of the bridge on the right side with the RPD excluded. Maximum biting was also performed on a wooden stick positioned in the molar region of the RPD on the right side with the RPD connected to the FPD. All the maximum loadings were done three times after each other, and the different loading situations were separated by a 5-min resting period.

Results

The deformation recorded at maximum habitual biting on the FPD with and without the RPD is given in Tables 1 and 2. The same general deformation pattern was found recorded in all the strain gauges used with the exception of the gauges positioned on the right cantilever part of the FPD (G7–G9). When the RPD was connected to the bridge, the deformation pattern shifted from contraction to elongation in gauges G7 and G8 at maximum biting. In strain gauge G9, elongation was recorded in this biting with

Table 1. Strain (με) and direction of principal strain in a fixed maxillary bridge with two bilateral cantilever pontics at maximum biting in central occlusion. The directions of the principal strains are in relation to the long axis of the cantilever bar. In the front the directions are given in relation to the long axis of the teeth. Positive values denote elongation, and negative values denote contraction

	Strain									Direction		
	Front			Left side			Right side					
Biting	G1	G2	G3	G4	G5	G6	G7	G8	G9	Front	Left side	Right side
1	−29	188	214	571	47	329	−36	−57	0			
2	−29	210	200	543	35	314	−36	−57	0			
3	−29	196	200	529	23	321	−36	−57	0			
Mean	−29	196	205	548	35	321	−36	−57	0	89	10	53
SD	0	7.3	8.3	21.8	11.6	7.2	0	0	0	3	3	2

the RPD connected. The numerical values of the deformation in all the gauges were approximately the same for the two experimental conditions with the exception of strain gauge G9, which did not show any deformation at all at maximum biting on the bridge alone. The degree of standard deviations (SD) was similar with or without the RPD included. Strain gauge G10 showed that in the midline of the palatal bar of the RPD compressive deformation occurred (Fig. 3).

When the subject bit on a wooden stick on the right cantilever portion of the FPD without the RPD, all the strain gauges underwent elongation, except for the three gauges on the left side, which did not record any deformation at all (Fig. 2).

With the RPD connected to the FPD and with a wooden stick placed on the molar region of the right side of the RPD, all the three gauges on the cantilever right side (G7–G9) recorded increased elongation at maximum biting (Fig. 3) compared with what was found when biting on the cantilever part without the RPD (Fig. 2). On the left side a small contraction was noted in all three gauges. In the midline of the bridge, contraction was found in strain gauges G1 and G2, and compared with the situation without the RPD the deformation here shifted from elongation to contraction. In strain gauge G3 the general deformation pattern was the same but to a lower level than was found with the RPD excluded. In this experiment the general deformation in the palatal part of

Table 2. The strain (με) and direction of principal strain in a fixed bridge with attached removable partial denture at maximum biting in central occlusion. The directions of the principal strains are in relation to the long axis of the cantilever bar. In the front the directions are given in relation to the long axis of the teeth. Positive values denote elongation, and negative values denote contraction

	Strain										Direction		
	Front			Left side			Right side			RPD			
Biting	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	Front	Left side	Right side
1	−36	217	157	586	47	329	86	29	43	−100			
2	−21	174	157	500	58	286	100	29	43	−86			
3	−29	188	157	557	47	314	86	29	29	−86			
Mean	−29	193	157	548	50	310	91	29	38	−91	92	10	97
SD	7.2	22.1	0	43.6	6.7	21.8	8.3	0	8.3	8.3	2	3	3

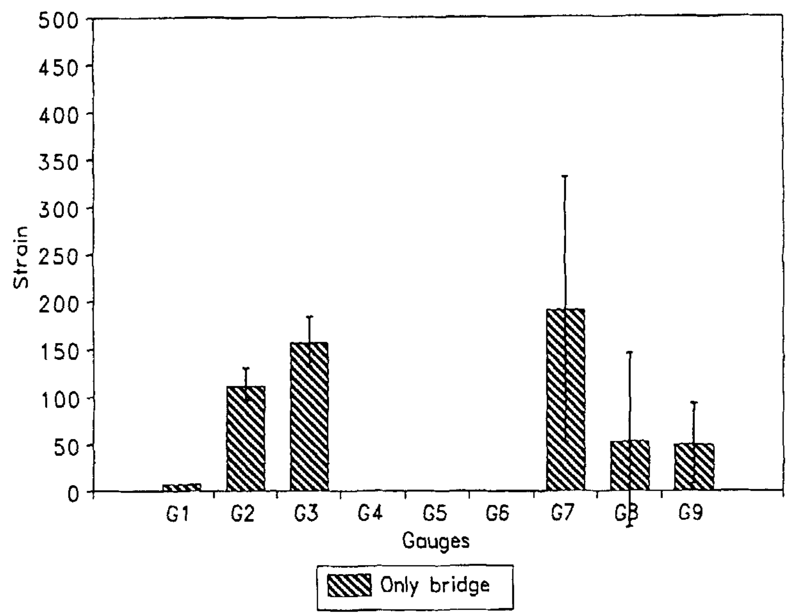

Fig. 2. Functional strain ($\mu\varepsilon$) in a cantilevered fixed partial denture at maximal biting on a wooden stick positioned over the distal cantilever unit of the bridge on the right side. Positive values denote elongation and negative values contraction.

the RPD was a minor elongation, compared with contraction at habitual maximum biting (Table 2).

Discussion

A high-gold FPD in combination with an RPD connected to the reconstruction with precision attachments was used in this investigation. Under functional conditions the RPD acted as an extended cantilevered reconstruction, and the only major difference was the palatal connector. At maximum habitual biting on the FPD differences were found in the deformation patterns between the left and right side. These dif-

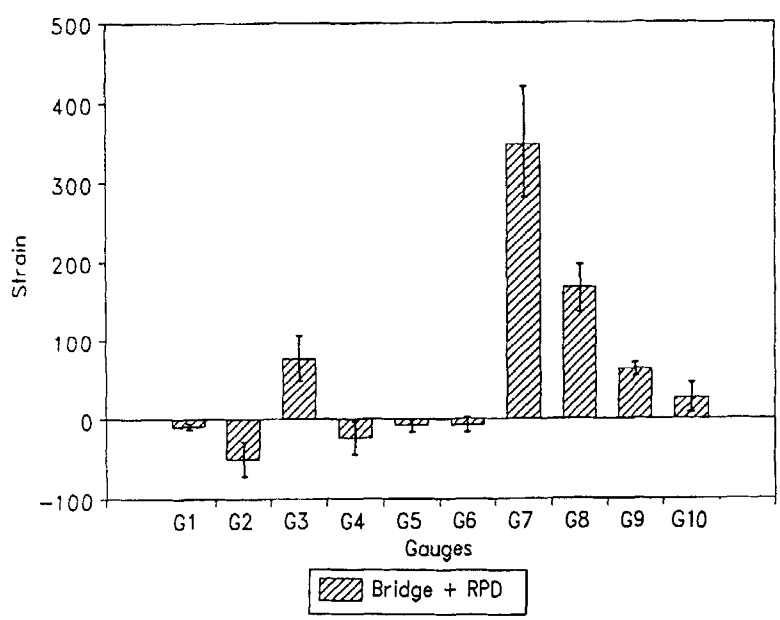

Fig. 3. Functional strain ($\mu\varepsilon$) in a cantilevered fixed partial denture in combination with an attachment-retained removable partial denture (RPD) at maximal biting on a wooden stick positioned in the molar region of the RPD on the right side. Positive values denote elongation and negative values contraction.

ferences were clearly seen even though the occlusal contacts were adjusted so that a stable occlusion was achieved and no clinical supracontacts were observed or recorded in occlusion. It is desirable to have an as even distribution of energy as possible over the complete reconstruction, to minimize local stress concentrations, but it is very difficult to plan for and design a reconstruction in which no local stress concentrations will appear under clinical loading conditions. When the RPD was connected, the same general deformation pattern was found in the front and left part of the bridge, but at the right side the deformation shifted from elongation to contraction. However, the numeric values at this side were comparatively smaller than at the left side.

When a local loading point on the cantilever of the FPD or the RPD was compared, more dramatic differences in deformation occurred. Increased elongation was found on the right side when biting on the RPD. The further away the loading position was located from the distal abutment tooth on the cantilever part of the reconstruction including the RPD, the more complex was the deformation pattern found. This is in accordance with the results given in experimental in vivo loading studies (3). With the RPD connected to the fixed bridgework, the deformation at local loading of the reconstruction was distributed over the entire reconstruction. Hence, the whole combined reconstruction will participate in distribution of the local forces. When the subject bit on the RPD, most gauges shifted from elongation to contraction both in the front and on the left side compared with biting on the bridge alone (Figs. 2 and 3). It is reasonable to believe that this depends on the major connector of the RPD, which from a biomechanical point of view keeps this combined fixed and removable system together, especially when no such findings were noted without the RPD. An RPD connected to an advanced fixed reconstruction will, even if the deformation pattern is complex, act and provide for a more favorable distribution of energy in the complete reconstruction. Here the RPD shows minor deformation itself even if local strain in the fixed part is considerably higher. The direction of principal strain showed only minor changes on the right side with and without the RPD.

In a previous investigation the same reconstruction was examined in a laboratory study (6). In that study the same simulated bitings were performed, and the results showed similar changes with and without the RPD in the same biting situations as above. However, the magnitudes and the types of deformation were different in some gauges. That means that major alterations of the design of a specific reconstruction can be examined in laboratory studies, but the general deformation pattern can only be seen in clinical experiments. It has been shown earlier that equal and clinically comparable conclusions cannot be drawn from laboratory studies (3, 8). Even if biologic tissues are simulated as far as possible by use of artificial materials in a laboratory deformation study, it is obvious that major differences in the general deformation pattern are to be seen in a laboratory study comparable with this clinical loading experiment. In a clinical loading situation all the concerned biologic factors will influence the general deformation pattern of an oral prosthetic reconstruction, and it is not possible to simulate all these factors in a laboratory loading experiment. The uneven distribution of the masticatory forces over the prosthetic reconstruction creates strain and stress concentrations in different parts of the reconstruction.

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