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Measurement of strains and stresses in fixed partial dentures

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The purpose of this study was to determine strain distribution in fixed partial dentures (FPD). The results of strain measurements in some specific regions of the FPD served as input data for an original computer-aided method of modelling and simulation of masticatory dynamics and strain distribution in FPD during mastication. The principal experimental findings show a proportional relation between the loads applied and the specific linear deformations of the surfaces of each FPD being analyzed.

Key words: strain distribution, fixed partial dentures, mastication

Analysis of functional strain distribution in FPD is important in order to prevent difficulties that occur after cementation of a FPD, such as retainer loosening, porcelain failures, and fractured connectors. These difficulties are often caused by the deformation of the FPD during mastication [8], [10].

For strain and deformation measurements, three all-metal (Gaudent alloy, Romania) maxillar FPDs were used. The FPDs were luted with zinc phosphate cement (Adhesor, Spofa Dental, Czech Republic) on an upper jaw acrylic model (figure 1).

The FPD's abutments were the maxillar canines, for the anterior FPD, the right second molar and the right second premolar, for the right posterior FPD, and the left third molar as well as the left first premolar for the left posterior FPD. The margin design was tangential and the abutment retainers were complete metal crowns (Gaudent alloy, Romania). Artificial alveolae for the abutment teeth were drilled in the maxillar model. Simulated physiological mobility of the abutment teeth was obtained by interposing a silicone impression material (Stomaflex Pasta, Spofa Dental, Czech Republic) between the artificial roots of the abutments and the alveolar walls. The opposing acrylic teeth were cast in one piece, together with the mandibular

model. The acrylic laboratory models were mounted on a custom-made verticulator instrument.

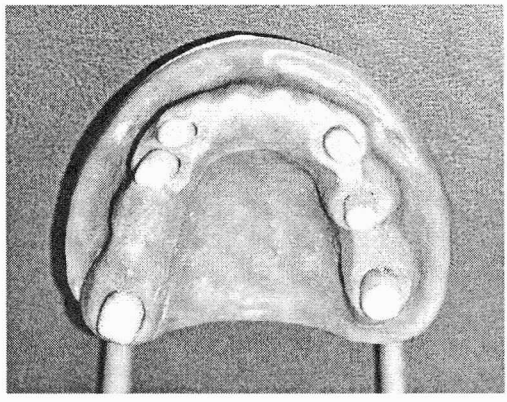

Fig. 1. Experimental model of the upper jaw

Figures 2 and 3 show the position of the strain gauges used for the measurements (LG 13-3/350, Hottinger Baldwin Messtechnik GmbH, Germany) on each of the three maxillar FPDs:

- Compression strain gauges on the bucal surfaces of the left central incisor ① and of the right canine retainer ②.
- Bending strain gauge on the bucal surface of the first left molar ③.
- Bending strain gauge on the lingual surface of the first right molar ④.

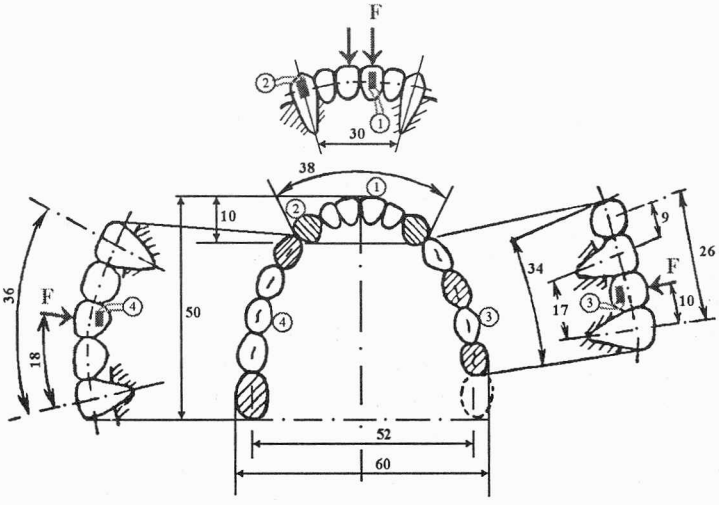

Fig. 2. Scheme of the experimental model showing the placement of strain gauges and loading positions of the three FPDs

The active and compensatory strain gauges were connected in a Wheatstone electric circuit, using a tensometric measuring bridge with 6 channels (N-2302) [1], [2], [6], [9].

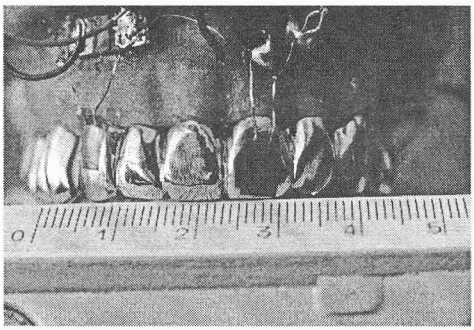

Fig. 3. Strain gauges on the left incisor and right canine

The balanced measuring instrument was then used to record the strain ε for different loads applied to the FPD with a lever loading device (figure 4).

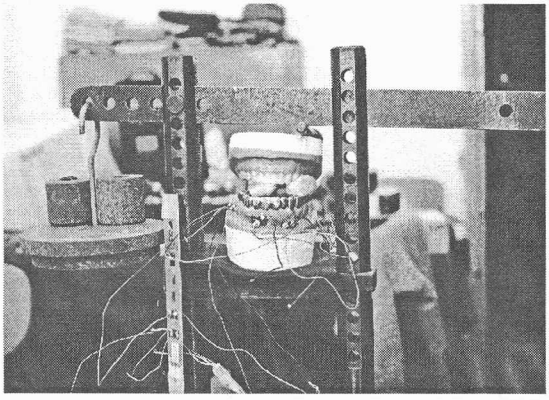

Fig. 4. Loading of the FPD

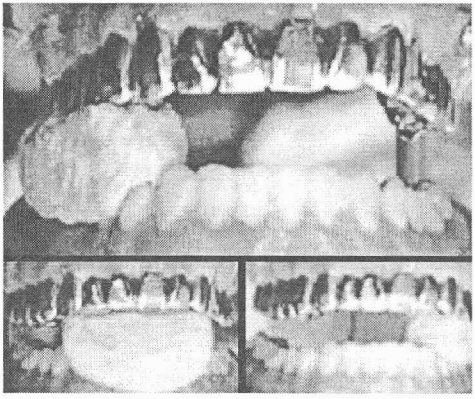

Fig. 5. The occlusal devices

The loads were applied to the three FPD's, both directly and using three occlusal devices in order to simulate load transmission through a food bolus [7], [10]. The occlusal devices were individually made for every FPD using elastic impression material (*Stomaflex Solid,* Spofa Dental, Czech Republic) (figure 5).

The measuring results are shown in tables 1 and 2. Using these numeric results, variation diagrams were plotted, showing the strain ε compared to the loads applied F (figures 6–9). Experimental strain measurement provides accurate information on compressive and bending strain distribution in fixed partial dentures. However, this information is limited by the number and placement of strain gauges on certain surfaces of the prosthetic structures [10]. Thus, this experimental study we continued complementary along with the research by developing an original computer simulation method of dynamic masticatory loads and their distribution in certain types of FPD [3], [4], [5].

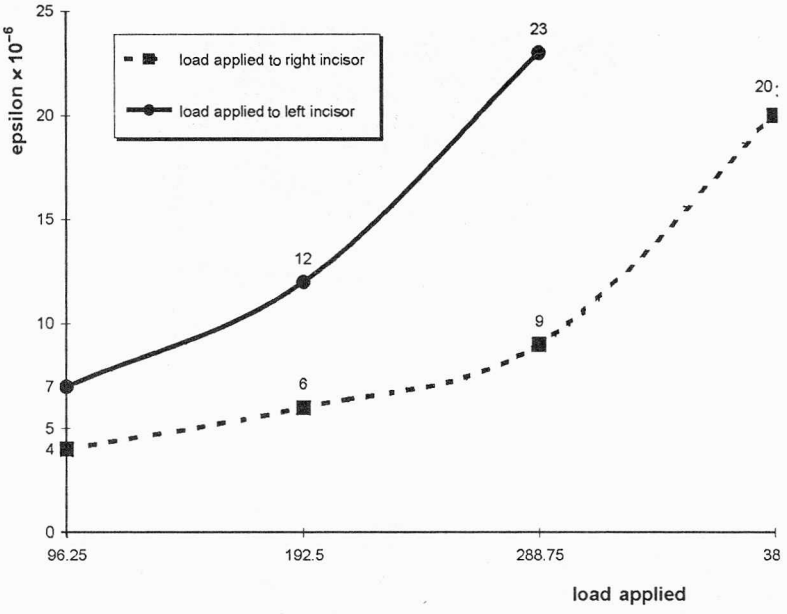

Fig. 6. Variation diagram (ε, F) measured in the left incisor

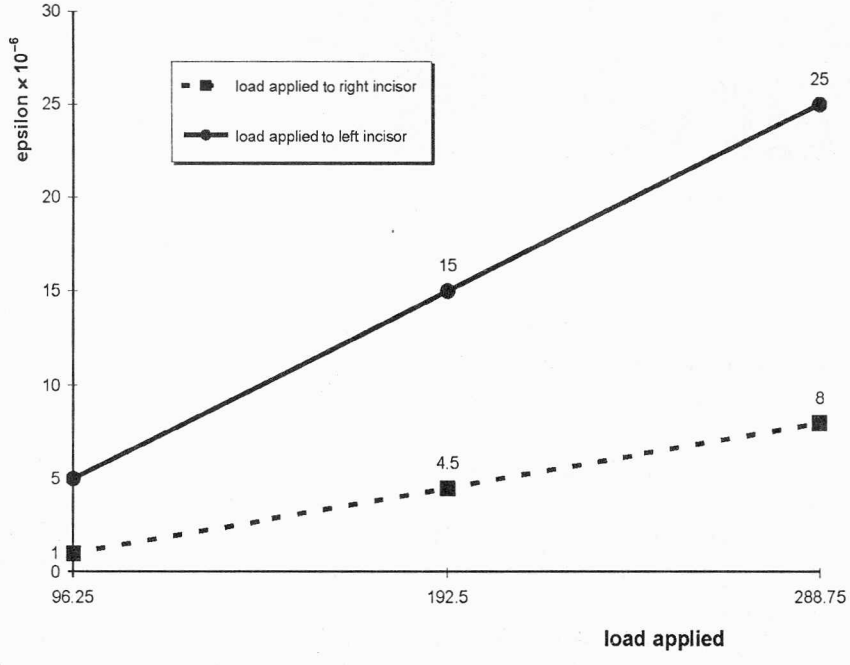

Fig. 7. Variation diagram (ε, F) measured in the right canine

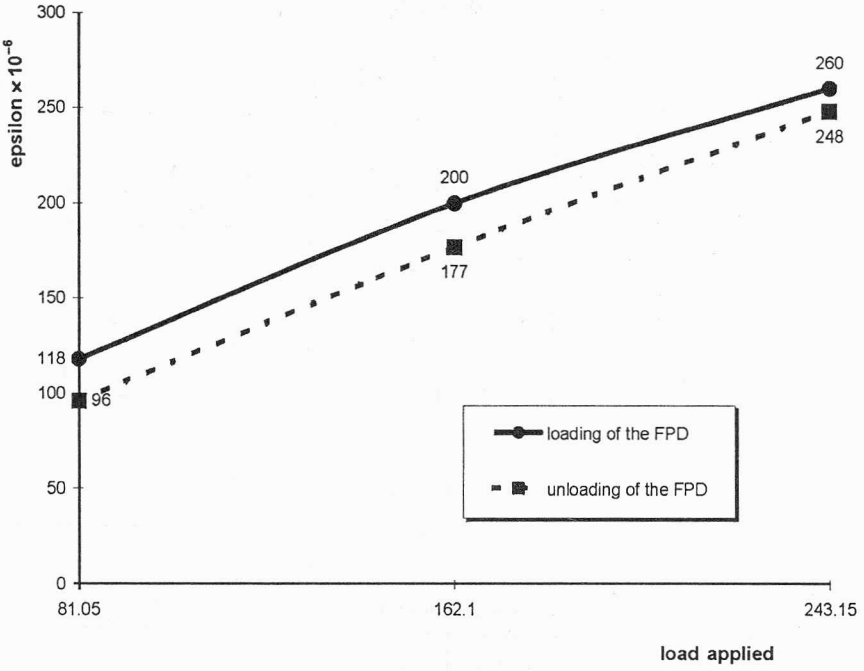

Fig. 8. Variation diagram (ε, F) measured in the first right molar

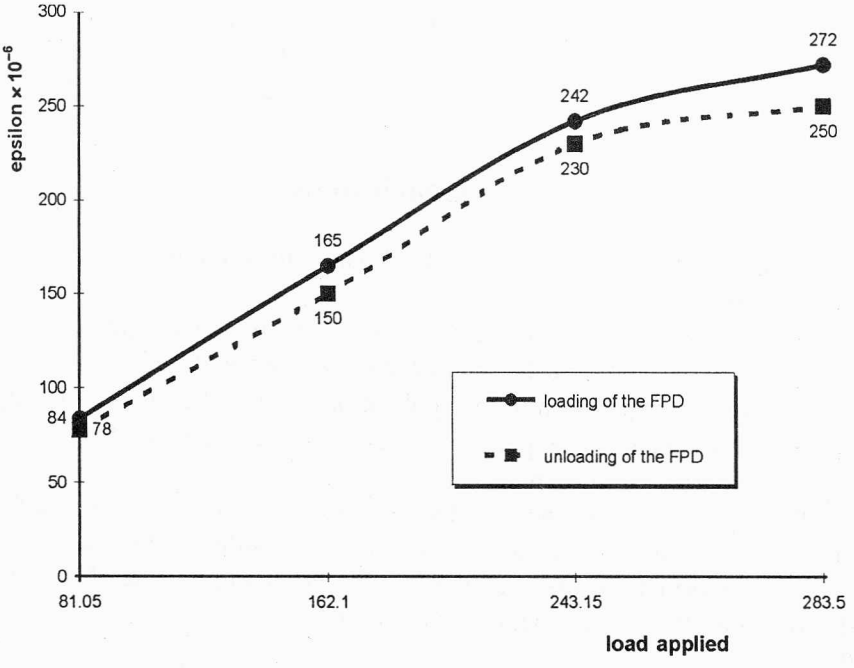

Fig. 9. Variation diagram (ε, F) measured in the first left molar

Table 1. Compressive strain in anterior FPD

No.	Force F applied [N]	Strain $\varepsilon \cdot 10^{-6}$			
		Load applied to right incisor		Load applied to left incisor	
		Incisor	Canine	Incisor	Canine
1	96.25	4	5	7	1
2	192.50	6	15	12	4.5
3	288.75	9	25	23	8
4	385.00	20	–	–	–

Table 2. Bending strain in posterior FPD

No.	Force F applied [N]	Strain $\varepsilon \cdot 10^{-6}$			
		First right molar		First left molar	
		Loading of the FPD	Unloading of the FPD	Loading of the FPD	Unloading of the FPD
1	81.05	118	96	84	78
2	162.10	200	177	165	150
3	243.15	260	248	242	230
4	283.50	–	–	272	250

Conclusions

By analyzing the surface strain of FPD using the strain gauge method, the following conclusions were drawn:

- There was a proportional relation between the loads applied and the specific linear deformations of the surfaces of each FPD being analyzed.
- Changes in the position of the application point of the load (as it happens during mastication) produced, as expected, a change in the corresponding values of ε, but still obeying a linear variation law.
- The significant difference in length between pontic spans of the left and right posterior FPDs was reflected in the measurement results by the fact that a given specific linear deformation was obtained for a higher loading value of the right posterior FPD compared to a lower loading value producing the same deformation of the left FPD.
- The results of this experiment are valuable starting data for an accurate computer-based modelling and simulation method of dynamic distribution of masticator loads in FPD.

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