Mandibular Implant-Retained Overdenture: A Clinical Trial of Two Anchorage Systems

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This in-vivo study aimed to investigate the load on the working-side implant and on the edentulous distal mucosa of the nonworking side in a mandibular implant-retained overdenture (MIR-OVD) anchored to 2 implants by either a ball- or a clips-and-bar attachment. Three female patients were provided with duplicate dentures anchored in the 2 ways. Strain on the implant was investigated using a strain-gauged abutment, and load on the mucosa was measured using a suitably placed load cell. Ball attachments appeared to provide greater stability to the MIR-OVD, since load was more evenly distributed onto the distal mucosa of both sides. When the MIR-OVD was bar-anchored, axial load on the working-side abutment increased.
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Key words: ball attachments, bar, implants, load, overdenture, strain gauges

The mandibular implant-retained overdenture (MIR-OVD) anchored to 2 implants is, in some situations, a solution to the problem of edentulism. Although many researchers[1–5] have stressed the short-term nature of current investigations into such types of rehabilitation, few studies have addressed load distribution on the implants.

In 1991 Jemt et al[6] compared the in-vivo load on MIR-OVD retained by 2 implants with the load on implant-supported fixed prostheses. They found that in MIR-OVD, part of the load was borne by the mucosa, resulting in a decreased load on the implants. They also found evidence of relatively high bending moment on the implants supporting the MIR-OVD. In 1992, through taking in-vivo 3-dimensional measurements using a strain-gauge technique, Mericske-Stern et al[7] determined that force magnitudes were lower in patients with MIR-OVD than in dentate subjects; moreover, vertical components of the loading force on the implants supporting the MIR-OVD were found to dominate. In 1995 Besimo and Kempf[8] compared 4 types of anchorage for MIR-OVD in an in-vitro study and found that load on implants may be affected by rigid splinting with a bar.

Although with MIR-OVD the general assumption is that the load is shared by the mucosa, to the authors' knowledge this has been demonstrated only indirectly.[6,9] The purpose of this in-vivo research, which follows up a study of the same topic using a mathematical model,[10] was to investigate the strain on the implants and the load on the distal mucosa in MIR-OVD, anchored either by ball attachment or by clips and bar.

Materials and Methods

Patient Group. The study group comprised 3 patients (white Caucasian females aged 72, 51, and 60 years, edentulous for at least 8 years). They had been treated at our clinic 3 years previously with a mandibular OVD anchored to 2 implants placed in the canine area to which were connected 5.5-mm titanium abutments (Nobel Biocare, Göteborg, Sweden). Anchorage was by means of ball attachments (Patients 1 and 3) or a straight bar (Patient 2), using the Nobel Biocare prosthetic protocol, which

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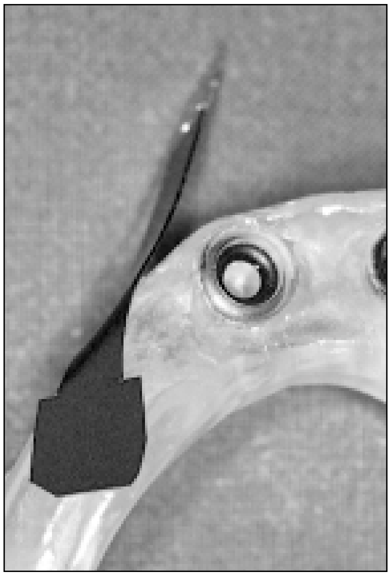
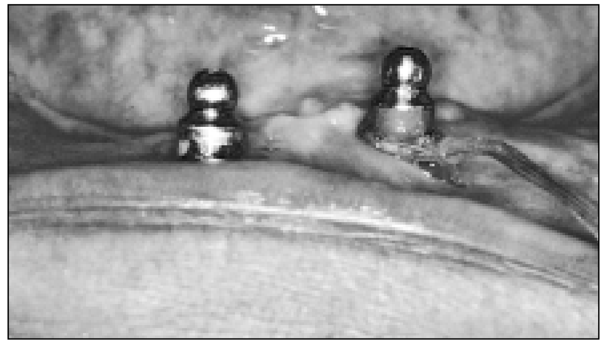


Fig 1a *(Left)* Photograph of the load cell cemented to the underside of the MIR-OVD.

Fig 1b *(Below)* Photograph of the strain-gauged abutment in place.



involved anchorage to the bar with 2 clips. These restorations were opposed by a maxillary complete denture. All 3 patients had undergone considerable mandibular resorption; bone quantity was C and bone quality was 3 according to the Lekholm and Zarb protocol.[11] Each patient's OVD was duplicated and the new OVD of patients 1 and 3 were fitted with a bar and 2 clips, and that of patient 2 was anchored with ball attachments.

Instrumentation and Recording Technique: Nonworking-side Mucosa. To evaluate the load transmitted by the prosthesis to the edentulous mucosa on the nonworking side, a 0.2-mm-thick load cell (Resistor Force Sensing, Interlink Electronics, Luxembourg) was cemented to the underside of the MIR-OVD (Fig 1) and connected to an A/D amplifier (MK 140/ef4, Galber ASE, Turin, Italy).

Instrumentation and Recording Technique: Working-side Abutment. To compare the 2 types of anchorage in terms of the strain produced in the abutment, a strain-gauge technique was used. The method of strain-gauging has been widely used to detect the strain induced inside a prosthetic structure by prosthetic procedures[10] or by masticatory load.[6,8,12–22] Strain gauges have been used in vivo[15,18] and in vitro[19] to study the load transmitted to the implants supporting mandibular fixed partial prostheses, to compare it with that on natural dentition,[20] or to assess the optimal arrangement and distribution of implants and cantilevers in different clinical situations.[9,14,21,22] Load distribution on implants in MIR-OVD has also been investigated via a strain-gauge technique.[6,7,12]

In the present study a method similar to that used by Glantz et al in 1993,[18] by Carr et al in 1996,[12,13] and recently by Mericske-Stern[12] was used. A 5.5-mm titanium abutment (Nobel Biocare) was equipped as follows (Fig 1): four 0.9-mm-long semiconductor strain gauges (Micron Instruments, Simi Valley, CA) were attached using 2-component epoxy-phenolic adhesive resin around the external circumference of the abutment 90 degrees apart, parallel to its long axis 2 mm from the top. The strain gauge characteristics were SS-Ø37-Ø22-5ØØP-S4 Standard matching; Length: 0.0037 in; Unbonded resistance: 500 Ω; matching ± 3 Ω (0/278°F); GF: 150 (78°F); TCGF: –13% (78°F/178°F); TCR: +17% (78°F/178°F). The position of the strain gauges was determined by trial and error to avoid breakage of the wires resulting from rocking of the teflon component of the attachment under masticatory load. The strain gauges were wired to an A/D amplifier (MK 140/ef4, Galber ASE, Turin, Italy) such that separate signals were produced from each. The 25 wires used were miniature insulated conductors made of stranded copper, size 36 and 50 AWG.

The geometry of the experiment is shown in Fig 2. By means of appropriate elaboration of the signals from the strain gauges, the axial force (f_z) along the Z-axis and the bending moment (m_x, m_y) around the 2 axes (X and Y), running through opposite sensors, could be reconstructed, where k_{33}, k_{13}, k_{24} are the calibration constants while Δv_{13} and Δv_{24} are the voltage differences measured in each pair of strain gauges.

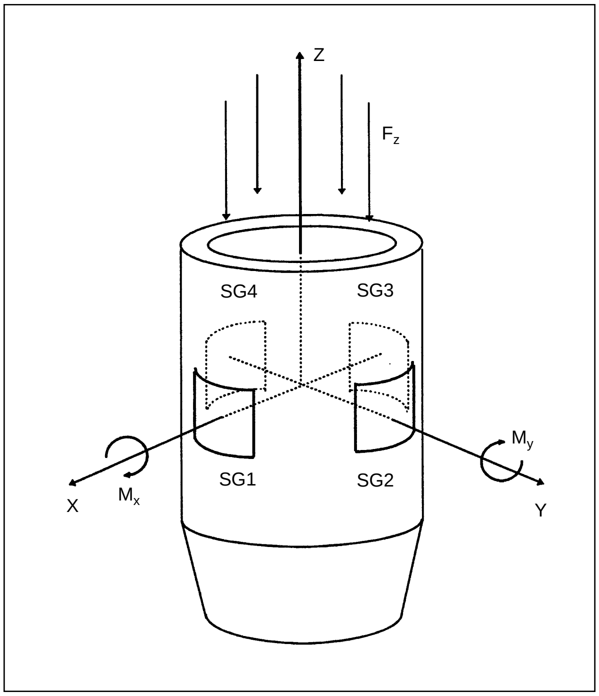
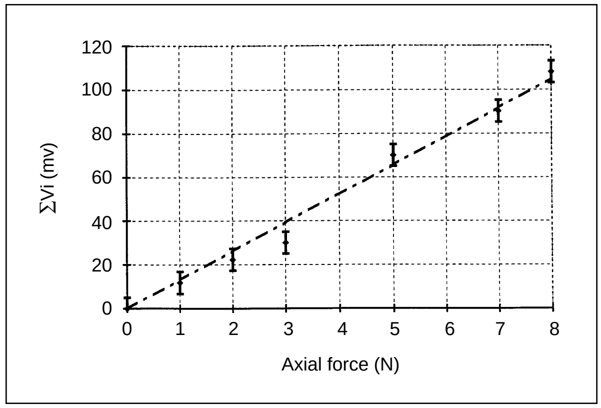


Fig 2 *(Left)* Diagram showing abutment and position of strain gauges. SG = strain gauge; M = moment; F = force.

Fig 3 *(Below)* Calibration of the strain-gauged abutment showing a typical calibration curve for axial loading.



$$f_z = k_{33} \cdot (v_1 + v_2 + v_3 + v_4),$$
$$m_x = k_{13} \cdot \Delta_{13}v, \quad m_y = k_{24} \cdot \Delta_{24}v$$

The strain gauges were calibrated for axial and bending loads. A typical calibration curve for axial loading is shown in Fig 3; the curve yielded to k_{33} = 13.1 N/mv; the calibration curves for bending loads are similar and give k_{13}, $k_{24} \approx 21.0$ N · cm/mv.

The bending load was represented by the total bending moment (M) in the X-Y plane, defined as follows:

$$M = \sqrt{m_x^2 + m_y^2}$$

Procedure: Biting Test. A bite plate was made from 2 layers of resin, incorporating a load cell of the same type as for the mucosa, for a total thickness of 5 mm, and specially shaped so as to remain stable during biting tests. Signals from the bite plate load cell were used to verify synchronicity between the masticatory cycle and load peaks on the nonworking-side mucosa and those on the working-side abutment. Instrumentation was completed with an A/D converter and a PC with tailor-made software (Programma di Gestione Carichi Masticatori, ESACOD, Torino, Italy).

To perform the trial on each patient, the working-side abutment was replaced with the specially equipped abutment described above (Fig 1b), and the ball-anchored MIR-OVD was inserted. The load cell was cemented to the underside of the denture at the mandibular first premolar area. When the denture was in place, the load cell was thus interposed between the denture and the mucosa. With the bite plate on the mandibular first molar, the patient was invited to make repeated biting movements for 10 seconds; the 10-second biting test was repeated twice more at 4-minute intervals. The trial was then repeated with the bar-anchored MIR-OVD.

Results

Nonworking-side Mucosa. In all 3 patients, the load on the edentulous distal mucosa on the nonworking side was far greater with the ball-anchored than with the bar-anchored MIR-OVD. Figure 4 illustrates the mean relative maximum load measured for each patient acting on the mucosa on the nonworking side for both methods of anchorage. It is significant that in patients 1 and 2, the mucosa on the nonworking side sustained almost no load when the MIR-OVD was bar-anchored; only in patient 3 was the mucosa loaded, even though the mean maximum load was about half that of the ball-anchored MIR-OVD in the same patient.

Working-side Abutment. With regard to the load transmitted to the abutment on the working side, the results were harder to interpret. Figure 5 illustrates the mean relative maximum axial and bending loads for each patient on the abutment in

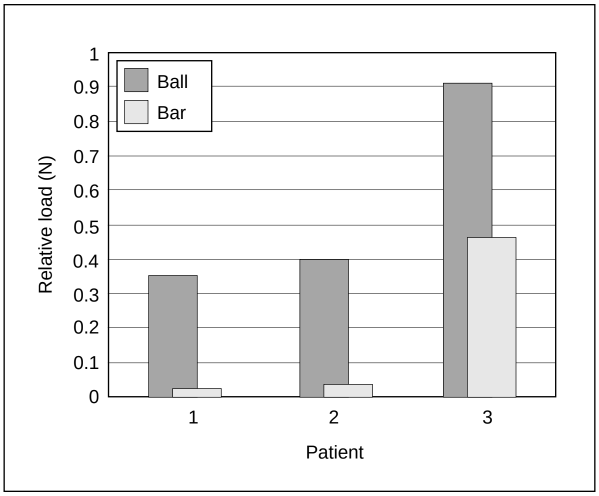


Fig 4 Mean relative maximum load on the edentulous distal mucosa of the nonworking side.

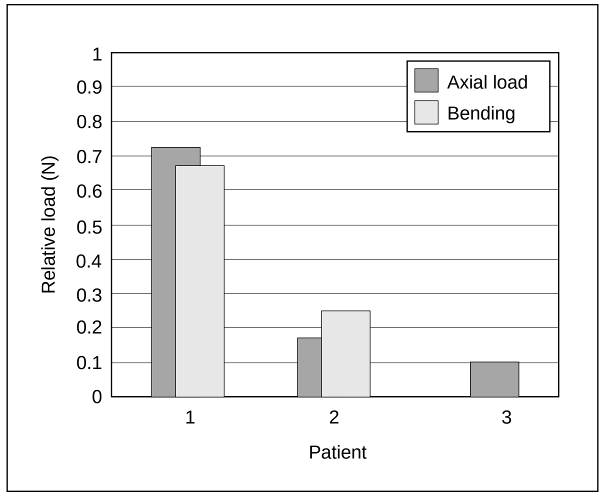


Fig 5 Mean relative maximum axial load and bending on the abutment of the working side in the ball-anchored MIR-OVD.

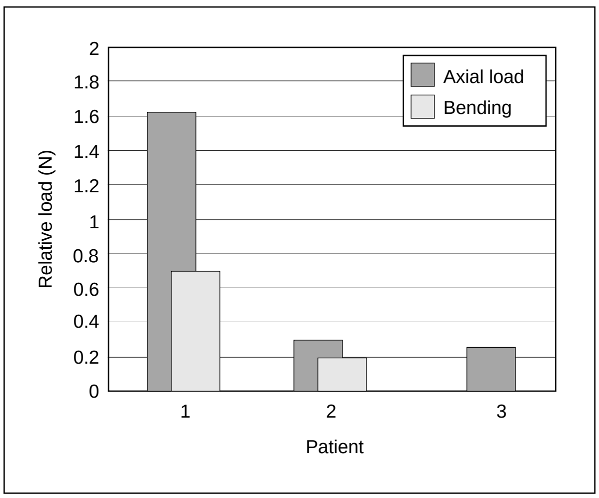


Fig 6 Mean relative maximum axial load and bending on the abutment of the working side in the bar-anchored MIR-OVD.

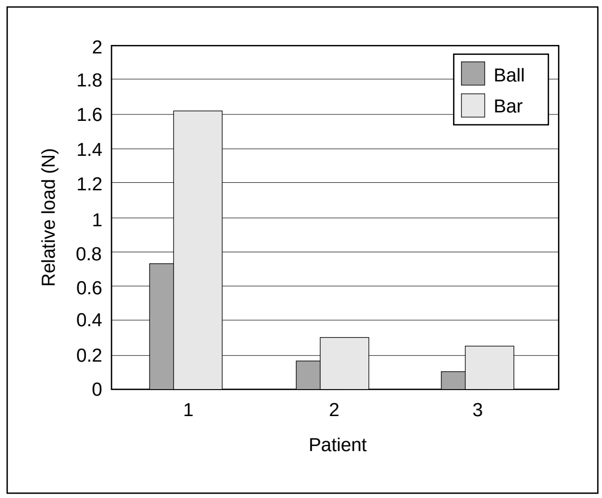


Fig 7 Mean relative maximum axial load transmitted to the abutment on the working side.

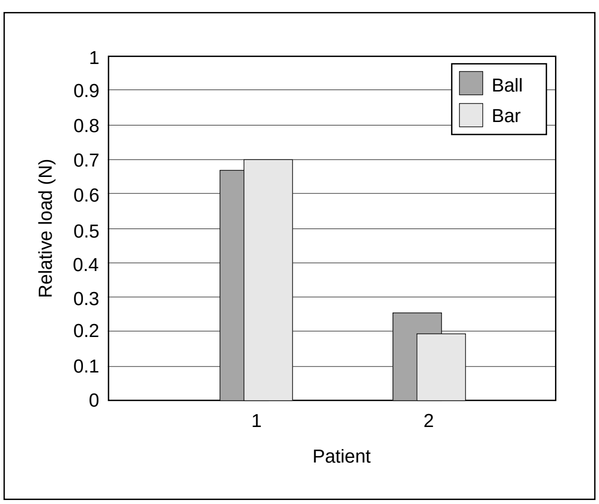


Fig 8 Mean relative maximum bending transmitted to the abutment on the working side.

the ball-anchored MIR-OVD. In Patient 1 the axial load was slightly greater than the bending load; for patient 2, the bending load was slightly greater. For patient 3, one of the 4 strain gauges broke during the last test, making it impossible to record the bending load data. It was decided that replacing and recalibrating the gauge would have altered experimental conditions. Figure 6 illustrates the mean relative maximum axial and bending loads on the abutment on the working side when the MIR-OVD was bar-anchored; in patients 1 and 2 axial load was greater than bending load.

Figure 7 shows that, in all patients, the mean relative maximum axial load was greater in bar-anchored than in ball-anchored MIR-OVD; the mean maximum bending load (Fig 8) was almost identical in patients 1 and 2.

Discussion

Nonworking-side Mucosa. The greater mean relative maximum load with the ball-anchored (Fig 4) than with the bar-anchored MIR-OVD appears to confirm the results obtained in a previous study using a mathematical model.[10] This increased load may be explained by the fact that when the MIR-OVD is ball anchored, it rotates predominantly around a single axis passing through 2 hinges (the ball attachments), thus distributing the load more evenly on the mucosa of the 2 distal ridges. When the MIR-OVD is bar-anchored, the 2 hinges (the clips) are closer together, which might allow the prosthesis to rock more freely. In patient 3, where there was also a load on the nonworking-side mucosa when the prosthesis was bar-anchored, the clips were further apart than in the other cases. The advantage of increasing the distance between the clips was clearly shown in the mathematical model.[10]

Working-side Abutment. These results were less clear. The fact that the axial load increases on the working-side abutment when changing from ball to bar anchorage may be explained by considering the load on the nonworking-side mucosa and the geometrical configuration of the 2 types of anchorage. Compared to ball anchorage, bar anchorage determines a load shift from the nonworking-side mucosa to the implants. The bar, which is firmly screwed in place and links the 2 implants, acts as a rigid splint between them and limits their freedom to bend. This might be one cause of the increased axial load observed on the nonworking side abutment.

Axial load on the working-side abutment appears to increase when changing from ball to bar anchorage. In a recently published study[12] Mericske-Stern observed that connecting the MIR-OVD to retentive ball anchors resulted in a slight decrease in maximum forces in the vertical direction. Many researchers have reported that vertical forces are less harmful than bending ones[6,7,23]; it remains to be determined whether vertical forces, which appear to be greater in the bar-anchored MIR-OVD, may compromise the longevity of the implants.

Conclusion

This limited clinical study, as well as the previous mathematical model research,[10] have suggested that when an MIR-OVD is anchored by means of ball attachments, more of the load reaches the nonworking-side mucosa. It would seem logical that the load is thus more evenly distributed on the 2 sides. The explanation may be that, if the distance between implants is equal, ball attachments are further apart than the clips, increasing the stability of the prosthesis. It still has to be determined whether and how the unequal load distribution to the edentulous distal ridges in the bar-anchored MIR-OVD will affect bone resorption in these areas.

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