The Influence of Loading Variables on Implant Strain When Supporting Distal-Extension Removable Prostheses: An In Vitro Study

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Purpose: The purpose of this study was to determine the implant stress under distal-extension removable prostheses (DERPs). ***Materials and Methods:*** A mandibular distal-extension cast and denture were fabricated. Strain gauges were attached to the implant, which was placed either parallel to the distal abutment or perpendicular to the ridge crest (inclined). Occlusal load was applied in five directions, and strains were compared using the Kruskal-Wallis test ($P = .05$). ***Results:*** When the implant was parallel, the strain was maximum at 20 degrees applied load direction. When the implant was inclined, the strain was minimum at 20 degrees mesial and maximum at 20 degrees applied distal load direction. ***Conclusions:*** Implant bending strain is reduced when the implant is loaded on its long axis and oriented parallel with the long axis of the most distal tooth. *Int J Prosthodont 2015;28:484–486. doi: 10.11607/ijp.4208*

Brudvik reported that a single implant supporting the distal-extension removable prosthesis (DERP) can improve stability[1] and that these prostheses seemed to be more effective than conventional DERPs.[2,3] In contrast, only a few reports have looked at the underlying implant. In regard to implant angle, Brudvik[1] also reported that the angle of the implant relative to the remaining abutments is not important as long as the implant abutment is not expected to carry an attachment component. In clinical application, there appear to be two main directions for fixing the underlying implant in the posterior region of missing teeth: parallel to the long axis of the most distal tooth and perpendicular to the anteroposterior slope of the alveolar ridge. However, there have been no mechanical reports comparing the implant angles, and the two directions chosen in this report were guided by the clinician's own subjective view and experience. Therefore, the purpose of this study was to determine the effect of the inclination of the implant supporting the DERP on strain incurred by the implant.

Materials and Methods

A unilateral mandibular distal-extension cast with simulated silicone mucosa (Fit Checker, GC) and DERP were fabricated using acrylic resin (Parapress Vario, Heraeus Kulzer) (Fig 1).

Two strain gauges (KFG-1N-120-C1-11L1M2R, Kyowa Electronic Instruments) were attached to the implant (4 mm diameter × 10 mm length, Biomet 3i). This implant was installed in the second molar region either parallel to the axis of the first premolar (parallel) or perpendicular to the anteroposterior slope of the alveolar ridge (inclined) (Fig 2). The opposing strain gauges were aligned mesiodistally.

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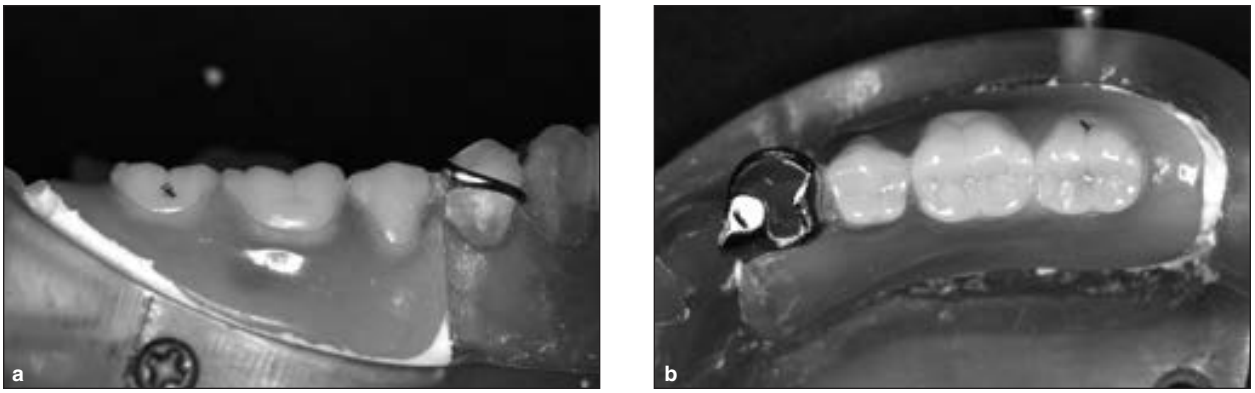

Fig 1 The mandibular cast and experimental denture. **(a)** Lateral view. **(b)** Occlusal view.

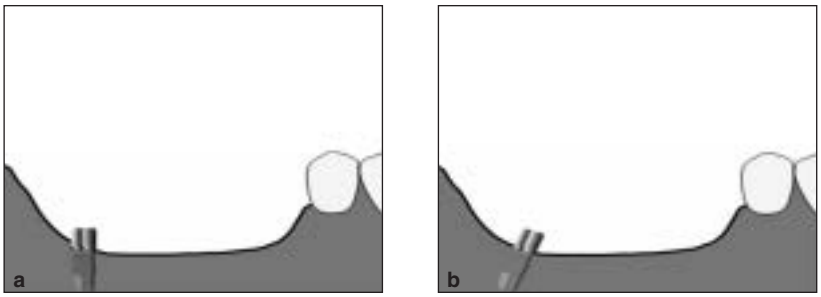

Fig 2 Implant inclinations. **(a)** Parallel. **(b)** Inclined.

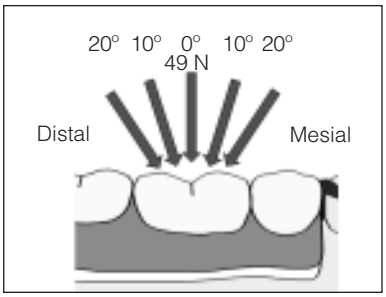

Fig 3 Directions of five loadings from 20 degrees distal to 20 degrees mesial.

A load of 49 N was applied to the first and second molars in five directions. These were perpendicular (0 degrees) and 10 degrees or 20 degrees mesial (m10 degrees, m20 degrees) or distal (d10 degrees, d20 degrees) to the occlusal plane (Fig 3). The bending strain was calculated for each. A negative value indicated that the implant was stressed from distal to mesial and a positive value the converse.

Comparisons of the strains were made using the Kruskal-Wallis test, with a post hoc comparison using the Steel-Dwass test ($P = .05$) and were performed with the statistical package R (version 3.02).

Results

With parallel alignment the strain was minimum at 0 degrees and maximum at d20 degrees. When inclined it was minimum at m20 degrees and maximum at d20 degrees.

When comparing loading location, most of the strains were smaller with the second molar than with the first in the parallel format, with opposite results obtained in the inclined format (Fig 4).

Discussion

Excessive marginal bone loss around implants in the absence of plaque-related gingivitis has been associated with occlusal lateral overloading.[4,5] These reports suggest that bending stress or lateral forces on the implant should be decreased as much as possible to maintain the residual ridge. Nevertheless, only a few studies have focused on underlying implants, and their characteristics under stress have not been reported. It is important to determine how implant-supported DERPs respond to implant stress and angulation to fully understand their benefits and scope of application.

The strain on the implant was minimum when loads were angled at m20 degrees in the inclined format. This may be because the inclined implant was angled at about 20 degrees mesial to the axis of the most distal tooth or the parallel implant, and the direction of implant and loading were similar at 20 degrees mesial loading. In the parallel format, the larger-angled loadings generated greater strains, with the minimum occurring when loading was 0 degrees. These results

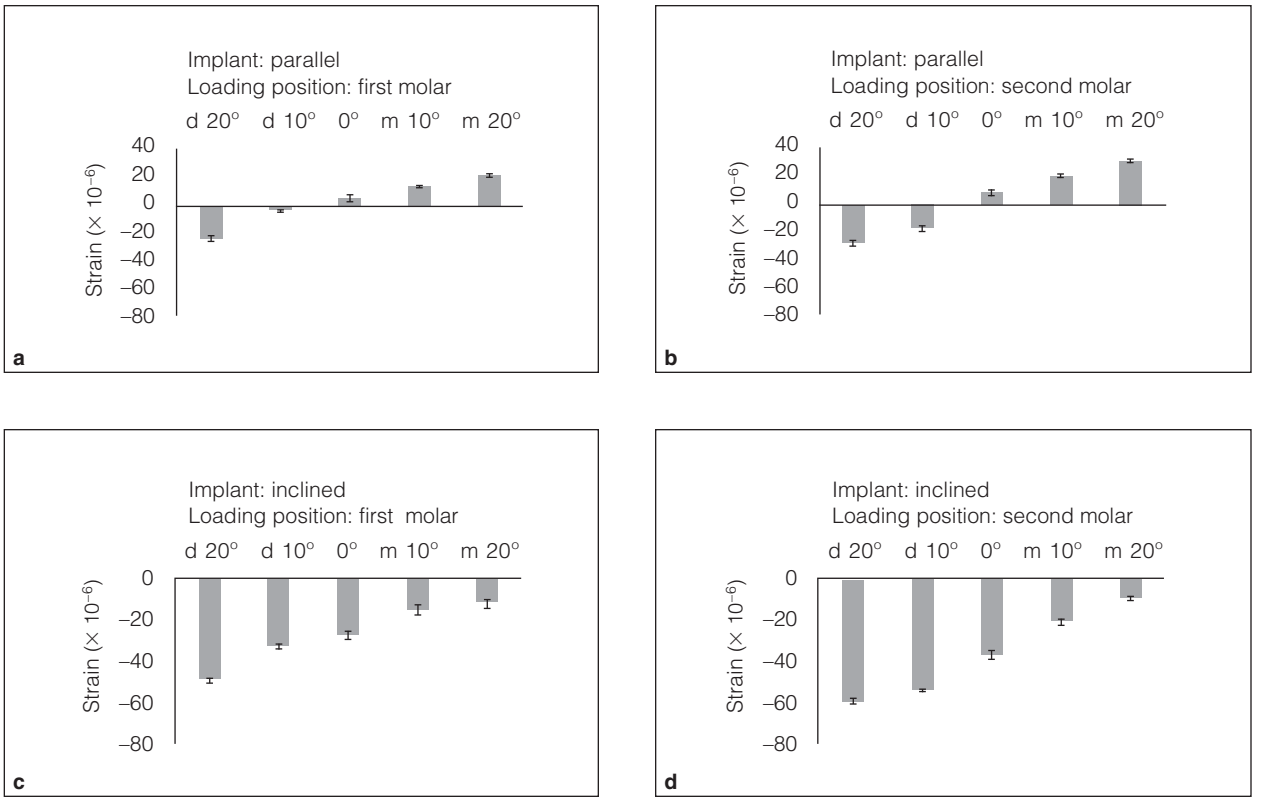

Fig 4 Graphs of bending strain of implants, under 49-N loading. Implant inclinations and loading positions are shown on each. Differences in mean values were analyzed using Kruskal-Wallis test with the Steel-Dwass post hoc test. There were significant differences among all data in all graphs ($P < .05$). d 20°= distal 20 degrees; d 10° = distal 10 degrees; 0° = perpendicular to the occlusal plane; m 10° = mesial 10 degrees; m 20° = mesial 20 degrees.

suggest that implants should be placed parallel to the axis of the most distal tooth and that the occlusion of IsDERPs should be adjusted so that the load is transmitted directly above the underlying implant. If the implant cannot be placed parallel, the occlusion should be adjusted so that the load is transmitted in line with the long axis of the implant or different attachments should be used to change the direction of the load.

Conclusion

Within its limitations, this study concluded that implant bending strain is smaller with the occlusal force coincident with the implant's long axis and when the implant is oriented parallel with the long axis of the most distal tooth.

Acknowledgments

The authors reported no conflicts of interest related to this study.

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