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Original article

Effects of different numbers of mini-dental implants on alveolar ridge strain distribution under mandibular implant-retained overdentures

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ABSTRACT

Purpose: To investigate the strains around mini-dental implants (MDIs) and retromolar edentulous areas when using different numbers of MDIs in order to retain mandibular overdentures.
Materials and methods: Four different prosthetic situations were fabricated on an edentulous mandibular model including a complete denture (CD), and three overdentures, retained by four, three or two MDIs in the interforaminal region with retentive attachments. A static load of 200 N was applied on the posterior teeth of the dentures under bilateral or unilateral loading conditions. The strains at the mesial and distal of the MDIs and the retromolar edentulous ridges were measured using twelve strain gauges. Comparisons of the mean microstrains among all strain gauges in all situations were analyzed.
Results: The strain distribution determined during bilateral loading experienced a symmetrical distribution; while during unilateral loading, the recorded strains tended to change from compressive strains on the loaded side to tensile strains. Overall, the number of MDIs was found to be passively correlated to the generated compressive strain. The highest strains were recorded in the four MDIs followed by three, two MDIs retained overdenture and CD situations, respectively. The highest strain was found around the terminal MDI.
Conclusions: The use of a low number of MDIs tends to produce low strain values in the retromolar denture-bearing area and around the terminal MDIs during posterior loadings. However, when using a high number of MDIs, the overdenture tends to have more stability during function.

1. Introduction

In some patients whose alveolar ridge morphology does not allow regular-sized implant placement without additional bone augmentation procedures, the mini-dental implant (MDI) may be an alternative form of treatment. These implants have been used to assist in the retention of overdentures in patients with atrophic ridges [1–4]. MDIs were able to retain the mandibular overdentures and showed that they can improve the quality of life of the patient, the degree of satisfaction of the patient, and the chewing ability of the denture-wearing patient [1,3].

Nevertheless, there are some concerns for patients who use MDIs. For example, some findings from the in vitro studies and the finite element analyses (FEA) have illustrated that stress values affecting the crestal cortical bone are reciprocal to the dental implant diameter and MDIs are prone to create a high level of strain in the bone around the MDIs as a result of the small diameter of the implant [5–9].

Although there are still concerns with regard to the negative biomechanical behavior of MDIs, the use of MDIs to retain overdentures has been continuously increasing [4,10]. In the edentulous mandible, four MDIs at the interforaminal region have been used for immediate loading with overdentures [1,3,11,12], whereas some authors have described an alternative method of retaining mandibular overdentures with only two MDIs [10,13,14]. Nevertheless, there has been limited available information regarding the number of MDIs and the amount of load transmitted to the alveolar ridge in MDIs-retained mandibular overdentures.

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Fig. 1. MDI compartments. MDI body (a), retentive screw (b), MDI body with retentive screw (c) and MDI with Equator retentive attachment (d).

This study was conducted to extend the overall understanding of the MDI number with regard to strain distribution. The objectives of this study are to observe the changes and relationships of the strains around the MDIs and the retromolar edentulous areas when using different MDI numbers to retain the mandibular overdenture.

2. Materials and methods

2.1. Specimen preparation

In this study, five MDIs, 2.75 mm in diameter and 12 mm in length, (PW+, Nakhon Pathom, Thailand) were used (Fig. 1). This MDI system consisted of two parts: the body and the retentive screw. The retentive screw head is designed to perform as a patrix of the retentive component, which will be joined in the matrix of the retentive attachment (Equator, Rhein83, Bologna, Italy).

Subsequently, each of the MDIs was coated with one millimeter of thickness of self-curing acrylic resin (Vertex Regular Crystal Clear, Vertex Dental B.V., Zeist, the Netherlands). After that, uni-axial strain gauges (KFG – 1N- 120- C1- 11N50C2; Kyowa Electronic Instruments, Tokyo, Japan) were attached in a vertical direction of the mesial and distal sections of the MDIs using a Cyano-acrylate based adhesives (CC-33A strain gage cement, Kyowa Electronic Instruments, Tokyo, Japan) (Fig. 2). MDIs locations were marked and drilled in the midline, lateral incisor, and canine regions of a simulated self-curing acrylic resin edentulous mandible model (Vertex Regular Crystal Clear, Vertex Dental B.V., Zeist, the Netherlands). All MDIs with attached strain gauges were placed parallel to one another using a surveying device (AF350 surveying and mulling device, Koblach, Austria). The distance between the center of the midline MDI and the lateral incisor MDIs was 5 mm, the distance between the centers of the lateral incisor MDIS was 10 mm, and the distance between the centers of the lateral incisor and the canine MDIs was 10 mm (Fig. 3).

All of the MDIs were then embedded into the model with the same materials until the same shape of the model was achieved. After that, the other two uni-axial strain gauges were oriented and attached in a bucco-lingual direction at the retromolar edentulous ridge of the simulated model. Therefore, a total of twelve strain gauges were used in this study. Each strain gauge has been labeled with an abbreviation (Fig. 4).

After the MDIs and strain gauges had been completely installed, the gingival tissue was simulated by being relined on the simulated model with polyether impression material (Impregum, 3M ESPE, St. Paul, Minn, USA) involving a uniform 2-mm-thick layer in the anterior edentulous area, and a 4-mm-thick layer in the retromolar area [15].

2.2. Overdenture fabrication

In this study, we used one mandibular complete denture as an experimental specimen by simulating four situations as follows: CD, 2-MDI, 3-MDI, and 4-MDI retained mandibular overdenture (Fig. 3).

With regard to MDIs retained mandibular overdenture fabrication, the five retentive screws of MDIs were put into all MDIs with an insertion torque of 20 N at the same time. The overdenture pick-up method were fabricated using self-cure acrylic resin (Rebase II, Tokuyama Dental Co. Tokyo, Japan) following the manufacturer's instructions. When tested in each situation, the retentive screws of the MDIs were removed or added, depending on the experimental group. Additionally, the denture base was adjusted to the untouched non-associated MDIs before being tested.

2.3. Loading application and strain measurement

In this study, 200 Newton (N) axial static loading was applied to the experimental overdenture through the use of a Universal Testing Machine® (UTM, Instron 5566; Norwood, MA, USA) for 15 s with the crosshead speed being set at 0.05 mm per minute [16]. This load level was selected as being within the range of normal occlusal mastication for implant overdenture patients that had been previously identified in literature [17,18].