Stress Analysis of an Overdenture Using the Finite Element Method

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The purpose of this study was to examine the influence of reinforcing the structure of an overdenture on stress distribution in the residual ridge using the three-dimensional finite element method. Four models of mandibular overdentures with various reinforcement methods were analyzed, including *(1)* without reinforcement, *(2)* with chrome-cobalt reinforcing wire, *(3)* with a reinforcing structure (a cast metal framework) and no reinforcement on the coping top, and *(4)* with a reinforcing structure and reinforcement on the coping top. The reinforcement adjacent to the top of the coping and the medial part reduces the stress beneath the loading side of dentures and widely and evenly distributes the stress of the residual alveolar ridge. *Int J Prosthodont 2013;26:340–342. doi: 10.11607/ijp.3421*

Reinforcement in overdentures is often used to prevent fracture and deformation.[1,2] A previous study[3] by the authors suggested that a simple reinforcement can reduce overdenture strain and prevent deformation. The purpose of reinforcement is not only to prevent fracture, but also to distribute the occlusal stress to the underlying denture-bearing areas as uniformly as possible to minimize bone resorption.[4]

The purpose of this study was to examine the influence of reinforcement of the overdenture on the stress distribution in the residual ridge using the three-dimensional (3D) finite element method (FEM).

Materials and Methods

Laser scanning of an edentulous mandibular model was performed with a noncontact 3D digitizer system (VIVID700, Konica Minolta). 3D parts were prepared with computer-aided design (CAD) software (SolidWorks) (Fig 1a). The abutment tooth had a coping with a dome-shaped upper surface and a height of 6 mm above the mucosa.

The four types of reinforcements of the experimental overdenture model were (Fig 1b) without reinforcement (S), with cobalt-chrome reinforcing wire having a diameter of 1.2 mm (W), with reinforcement and no reinforcement over the coping top (CA), and with reinforcement and reinforcement over the coping top (CB). CA and CB were cast metal frameworks with a width of 4 mm and a thickness of 1 mm.

3D models were analyzed by FEM (Cosmos Designstar, SRAC). A gap element was used to simulate the true behavior of the overdenture. A vertical load of 49 N was applied on the occlusal surface of the first premolar position (P1) and the second molar position (M2). The von Mises equivalent stress in the surface element of the residual mucous membrane was examined by linear static analysis. The sum of the stress and the maximum stress in the residual ridge were evaluated. The values for the elastic modulus and Poisson ratio of the materials were set according to former studies (Table 1).[4,5]

Results

The sum of the stress when loading on P1 was smaller than when loading on M2. When loading on P1, the total stress became smaller in the order of S, W, CA, and CB. When loading on M2, there was no difference in the sum of the stress among all of the experimental dentures (Fig 2).

The maximum stress when loading on P1 was smaller than when loading on M2. The maximum stress of CB was smaller than those of the other overdentures

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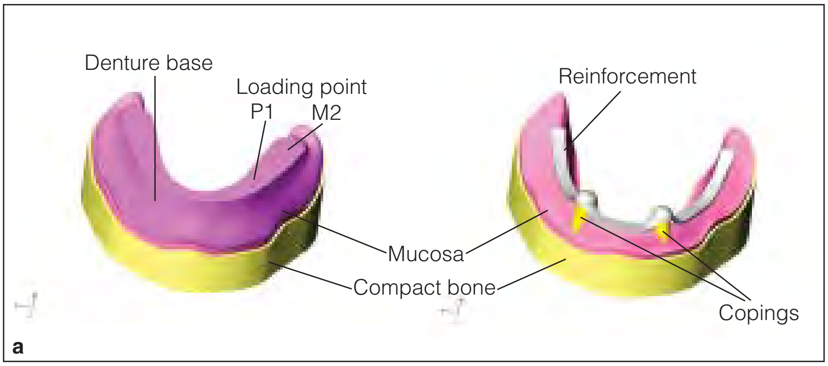
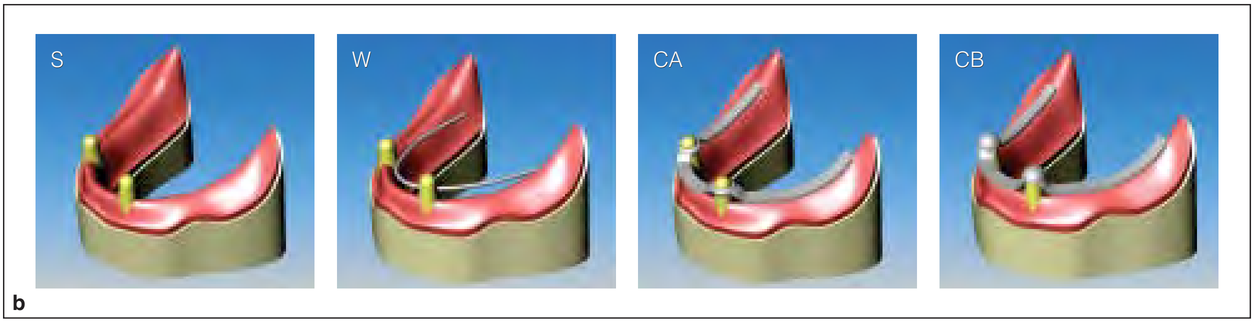
Fig 1 Schematic diagram of the model and **(a)** the loading points on the overdenture and **(b)** four types of reinforcement in the experimental models. P1 = first premolar; M2 = second molar; S = without reinforcement; W = with cobalt-chrome reinforcing wire (diameter: 1.2 mm); CA = with reinforcement and no reinforcement over the coping top; CB = with reinforcement and reinforcement over the coping top.





under each loading condition. The maximum stress became smaller in the order of S, W, CA, and CB overdentures under each loading condition (Fig 2).

For loading on P1 and M2 in all dentures, the stress was more than 0.001 MPa and is shown in Fig 3 as the red area on the loading (left) side. For loading on M2 in dentures S, W, and CA, there was a small area of over 0.001 MPa, which is shown in red, and in denture CB, there was a broad area of over 0.001 MPa on the balancing (right) side (Fig 3).

Table 1 Material Properties

Material	Young's modulus (MPa)	Poisson ratio
Denture base (acrylic resin)	4,000	0.3
Coping (Au-Ag-Pd alloy)	78,400	0.33
Mucosa	10	0.45
Compact bone	10,000	0.3
Reinforcement (Co-Cr alloy)	200,000	0.3

Discussion

The large deformation in the overdenture without reinforcement resulted in high stress on the working side and considerably lower stress on the balancing side. Conversely, increasing the strength of the overdenture by reinforcement decreased the deformation of the denture base and decentralized stress to the balancing side, thereby decreasing stress on the working side.

Pain and ulcers occur in the mucous membrane because large loads act on a small limited area. Also, stress concentration in a certain area can be the cause of bone resorption. It has been suggested that reinforcement can prevent both the deformation and fracture of a denture, as well as pain and the incidence of ulcers in the mucous membrane, by improving the strength of the denture by reinforcement and by distributing the stress to the mucous membrane.

Conclusions

Within the limitations of this research design, the following conclusions can be drawn. In the experimental overdenture without reinforcement (S), the total stress and the maximum stress in the residual ridge were large. Second, the reinforcement over the coping top and the median line reduces the stress beneath the loading side of the denture and distributes the stress of the residual alveolar ridge area widely and evenly.

Acknowledgments

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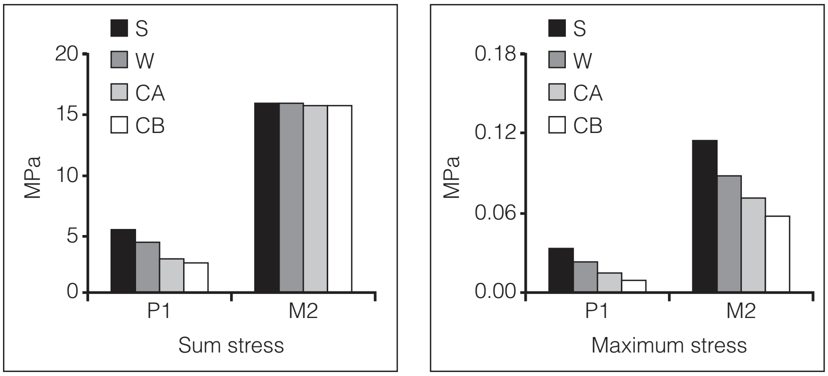

Fig 2 The sum stress and the maximum stress in the residual ridge (von Mises equivalent stress). P1 = first premolar; M2 = second molar; S = without reinforcement; W = with cobalt-chrome reinforcing wire (diameter: 1.2 mm); CA = with reinforcement and no reinforcement over the coping top; CB = with reinforcement and reinforcement over the coping top.

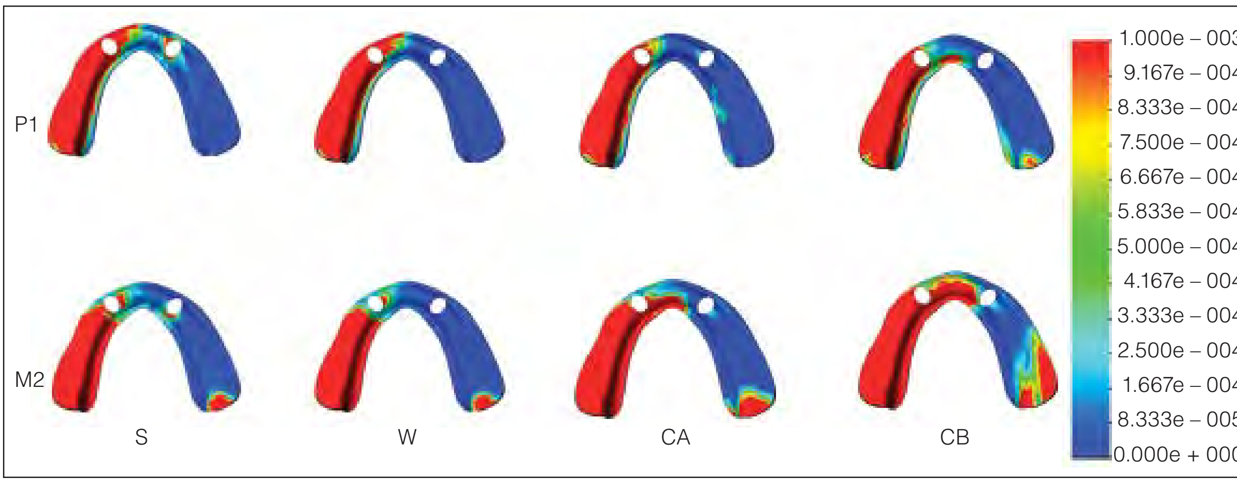

Fig 3 Effect of reinforcing structure on stress distribution in the residual alveolar ridge. P1 = first premolar; M2 = second molar; S = without reinforcement; W = with cobalt-chrome reinforcing wire (diameter: 1.2 mm); CA = with reinforcement and no reinforcement over the coping top; CB = with reinforcement and reinforcement over the coping top.

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Literature Abstract

Tooth loss and osteoporosis: To assess the association between osteoporosis status and tooth number

This study aimed to investigate the link between the osteoporotic condition of patients and number of teeth. Confounding factors such as age, smoking status, alcohol consumption, and hormone replacement therapy were also taken into account. From March 2008 to June 2010, 359 patients from the Manchester, UK, region were recruited. Each patient had a dental panoramic tomograph taken and the number of teeth were counted during dental charting. Data such as osteoporotic condition, smoking status, alcohol consumption, age, and use of hormone replacement therapy were collected. Complete data were obtained from 333 patients of which 90 patients were osteoporotic. Analysis using SPSS software (version 19) showed a significant relationship between molar tooth number and osteoporotic status (P = .017, 95% confidence interval: –1.339 to –0.137). The authors concluded that clinicians should educate osteoporotic patients of the higher risk of tooth loss and implement intensive preventive measures for them.

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