Original Research

Evaluation of Strain Distribution in Bone around Implant in Treatment Design of Overdentures Using Computer and Modeling of Finite Elements

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Abstract

Introduction: Introduction: Few studies have investigated the distribution of stress around implants. In this study the distribution of stress in bones around implants was investigated in five overdenture (OD) treatment designs including OD-1, OD-2, OD-3, OD-4 and OD-5. **Materials and methods:** The Catia modeling software was used in order to simulate the tooth/implant model and bone. First, the borders of cancellous and cortical bone in each section of the CT images were attained by Photoshop software. Then, modeling softwares SolidWorks and NUMBER were applied to make the final three-dimensional model of jaw. Finally, the amount of stress on the surface of bone/implant was studied by means of stress analysis software (Ansys v11.0). **Results:** Protrusive movements of implants B and D in OD-1 showed the highest amount of strain, 2435 εμ. Also, high amounts of strain, 1668 and 1557 εμwere observed in OD-1 and OD-2 designs in lateral movements respectively. **Conclusion:** The bottom line is that no forces to the extent of destruction based on the Ferost model were found for these designs. The highest amount of strain occurred in OD-1 design, which is held in mild overload window. Moreover, the amounts of strain in the rest of designs investigated were in adaptive window.

Key words: Dental implant, stress distribution, overdenture, Frost model.

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Introduction

Recently, treatment of edentulous patients by implant overdentures has become very common (1, 2). Nowadays, many attachments are used to support implant overdentures and treatment of patients with two implants and a bar attachment is very reliable (3, 4) even though there are different opinions regarding stress distribution in ball and bar attachment systems (5, 6). Based on the viewpoint of Carl E.Misch (7), the bone available in the anterior part of mandible is divided into five equal parts, named A, B, C, D and E as potential parts for implant . Carl E.Misch introduced five treatment-organized selections for implant-retained mandibular overdentures in edentulous patients (OD-1, OD-2, OD-3, OD-4 and OD-5) (Fig. 1).

In the first treatment design (OD-1), two implants are held in regions A and B; the implants are independent of each other. In the second treatment design (OD-2), the implants are not placed in the locations B and D and are splinted together by means of a suprastructure without any distal cantilever. In the third treatment design (OD-3), three root form implants are placed in locations A, C and E without any distal cantilever, the implants are connected together, but in treatment design three (OD-3) three implants are placed in locations B, C and D. In the fourth treatment design (OD-4), four implants are placed in locations A, B, D and E. Endosteal implant is an alloplastic material, placed in a rich bone by surgery serving as substructure of dental prosthesis (8, 9)

An appropriate endosteal implant can protect the width and height of the bone (10, 11). In partially edentulous patients, replacement of a single tooth with an implant can protect adjacent natural teeth and prevent following limiting problems such as caries, porcelain breakage and inappropriate beauty which are the most common causes of failure in fixed prosthesis (12, 13). The ideal objectives of modern dentistry are the simulation, performance, convenience, beauty, speech and health of patients (14). The Finite Element Method is widely applied in structural mechanics; moreover, it is also used for the solution of different engineering issues such as heat transfer, electric fields and so forth (15, 16). In recent years, most of studies on implant, particularly overdenture implants have been based on using the Finite Element Analysis, none of which have investigated stress distribution in bones around implant in any of the treatment designs introduced by Carl E.Misch; moreover, these studies were not comprehensive and nor were they performed in all functional movements. Thus, in this study we investigated stress distribution in bones around the implant in all treatment designs and all functional movements by means of a three-dimensional study of finite elements for the first time in order to simulate more real conditions of the mouth. Furthermore, through this study, we can choose the best design in terms of biomechanical principles and compare thestress distribution among the studied designs.

Materials and Methods

In order to simulate the model of teeth/implant and bone, CATIA software (IBM, Kingstone, NY; version 5) was used. Three-dimensional plan of jaw was designed by radiographic sections with thermography techniques. First, the border of cancellous and cortical bone at each section of CT images (obtained from the mandible of a real patient) was attained by photoshop program. Then, the curve of different sections were attained and transformed to data useable for modeling programs. The final three-dimensional plan of jaw was made for the five designs of study by using the software Solidworks (version 2012) and Number modeling. Cancellous and cortical bone, mucus and titanium alloys were designed based on physical properties gained from clinical studies (17-19).

A force of 100 N was applied to the models in protrusive and lateral movements. Based on the Gysi's facet theory (20), applied forces might vary according to cusp contacts on balancing anterior faucets. In order to analyze the final models, the fine and separate models as well as the final assembled models were entered to the software of ANSYS Workbench. (Figs. 1-6).

The amount of stress on the surface of bone/implant was assessed via software Ansys v11.0. So as to generate a network in Workbench® 6 software, we used tetrahedron elements. In some areas of networking, finer elements were used considering required accuracy for solution; this issue can be seen in networking images. After networking, the static analysis of the model was done by this software. An example of the networking has been shown in Figure 7 for the fifth treatment design (OD-5). (Fig 7).

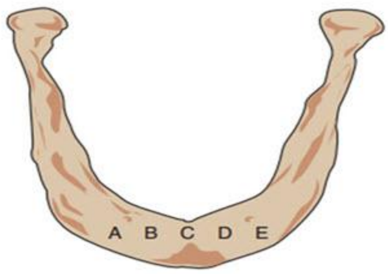

Figure 1. Location of the implant based on MISCH

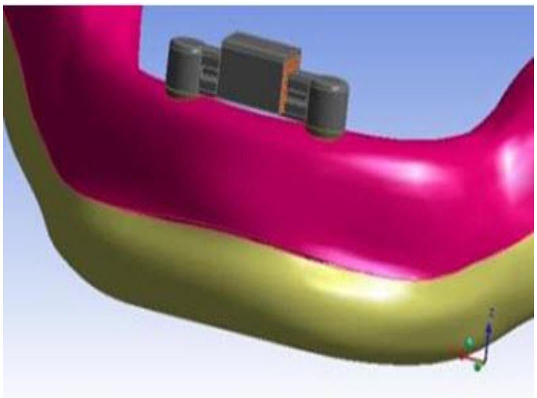

Figure 2. Schematic diagram of OD-1 treatment design

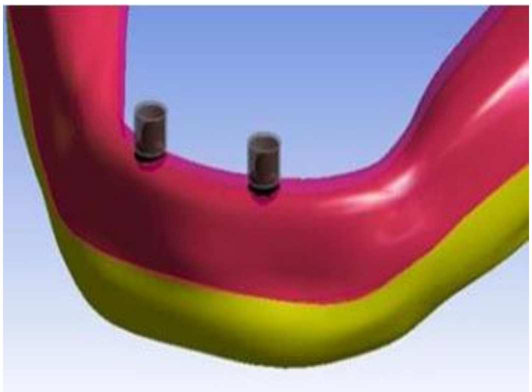

Figure 3. Schematic diagram of OD-2 treatment design

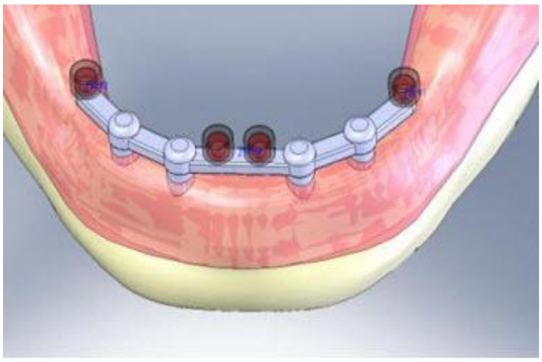

Figure 4. Schematic diagram of OD-3 treatment design

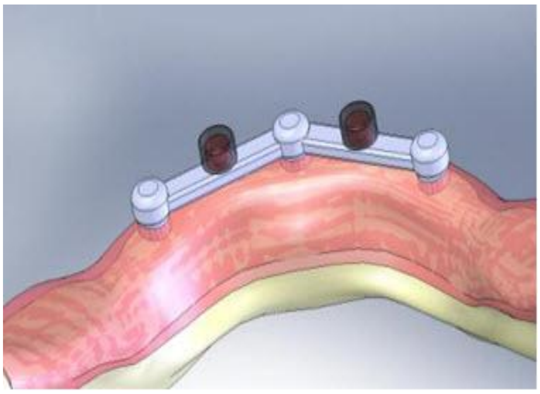

Figure 5. Schematic diagram of OD-4 treatment design

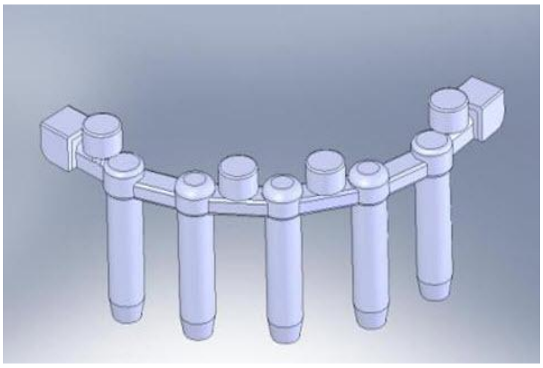

Figure 6. Schematic diagram of OD-5 treatment design

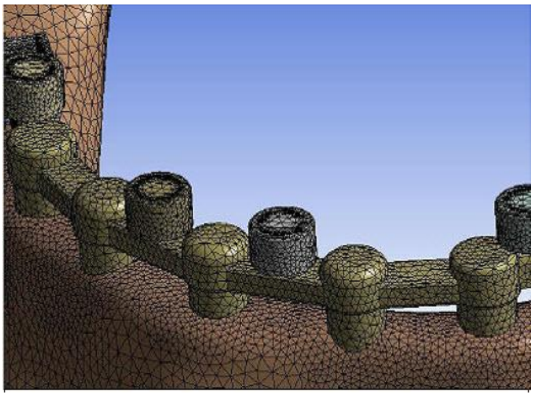

Figure 7. Schematic diagram of networking OD-5 treatment design

Results

The findings of protrusive movements in OD-1 showed that the highest strain was 2435 με mostly observed in upper edge of the implant and bone on the left side cut as well as in the apical third of implants in the right side. The least strain was seen in two cuts in the bone around the middle third of the lingual surface of implants, the border of the middle third and apically lingual surface of the implant in the left side cut and a little area in the middle third of the implant in the right side cut. In lateral movements, the highest level of strain was 1668με and most of which was seen in two locations of the implants B and D, both right and left cuts of these implants, cervical region of implants, one-fifth of apically implant and the bone around it; and, the least strain was in the middle third of the implant.

The findings related to protrusive movements in OD-2 showed that the highest amount of strain was 1179 εμ, most of which was seen in both right and left cuts of contact area between the apical and the middle third of the lingual surface of implant B and the bones around it and also in location D, the right cut in the border between the apical and middle third of the lingual and middle surface and in left cut in a little area in the border between the apical and middle third of the buccal surface of the implant. Furthermore, the least strain around implant B was observed in the right cut in the cervical bone adjacent to the middle of the lingual surface of the implant and in left cut in upper half of the lingual surface and its adjacent bone, in implant D ,in right cut, in cervical two-third of lingual surface and the cervical bone adjacent to the lingual surface and cervical two-third of the buccal surface of the implant and in left cut in the cervical of the implant and the adjacent bone and some areas in the middle area .

Regarding the lateral movements in this study, the highest amount of strain was 1557 εμ mostly in left cut of apical and buccal surfaces and the bone around the apical and lingual surface of the corner of the implant in both implants B and D and in right cut in the border of the cervical and middle third of the lingual surface of the implant. The cervical third of the lingual surface and its adjacent bone showed the least strain in both cuts. The right cut in location B was in two-thirds cervically of the middle surface and in location D was obsereved in two-thirds cervically of lingual surface of the implant .

In design OD-3A, the highest strain (1023 εμ) was observed in locations A, C and E;however, in lateral movements the highest strain was only 855 εμ.

The results for protrusive movement in design OD-3 A showed that the highest amount of strain was 980 εμ occurring in locations B and C, while in lateral movements it was 1047 εμ, which was similar for the three implants.

The results for protrusive movement in design OD-4 showed that the highest level of strain (1093 εμ) was in locations A and B and 907 εμ in lateral movements, which was similar for the four implants.

In design OD-5, the highest level of strain (1339 εμ) was in locations A and B, illustrating that strain was distributed steadily in all surfaces of implants and the bone around it. However, lower amounts of strain was seen in the middle areas of the implant, the bone adjacent to the apical region of the implant as well as the cervical two-thirds of the buccal surface and its adjacent bone strain.

Discussion

In this study, no forces to the extent of destruction based on the Ferost Model was found (21); moreover, in some areas a strip of least strain was seen that according to Ferost theory is in the range of atrophy. However, in view of the fact that these areas in other movements are subject to forces, the possibility of atrophy is very low.

In this study, the highest amounts of strain were in protrusive movements of implants B and D and in lateral movements in OD-1 and OD-2 strain, which are held in overload mild window showing high pressure on the implants and the bone around them, which can be worrying in patients having deep bite occlusion .

The highest level of strain in protrusive movements in OD-1 design is in the contact area between the upper edge of the implant and the bone apical two-thirds strain. Also, in this design, a high level of strain was applied to the implants and the bone around them in lateral movement strain. It should be noted that the strain due to lateral movements in OD-2 design in both group function and canine rise occlusion is held in overload mild window.

The amount of strain in protrusive movements in OD-2 and in protrusive and lateral movements in OD-3 were so high as to be held in the range of the adaptive window. This illustrates that forces are distributed appropriately among these designs and can be attributed to the function of horizontal bar connecting the implants and subsequently decreasing the level of strain either in protrusive or lateral movements compared with OD-1 and OD-2 strain. Although in lateral movements the difference of maximum forces is lower than protrusive movements, the region of force spread in design OD-2 is by far lower than in design OD-1.

In general, the highest amount of strain in protrusive movements was for implants A and B in OD-5 design while in lateral movements, implants B, C and D in OD-3 design showed the highest strain. Since all these figures are explained as adaptive window, it can be concluded as follows: OD-1 design was the weakest both in protrusive and lateral movements, OD-2 design proved to be better than the first design. Other designs OD-3, OD-4 and OD-5 were more reliable because in none of the areas and movements did the highest level of strain exceed that of the adaptive window. Despite the fact that a strip of least strain was observed which according to the Frost Theory is in the atrophy range, in view of the fact that these areas may be under forces in other movements, atrophic process seems improbable. As the applied force in this study (100 N) was determined based on or existence of natural teeth in upper jaw and implant-retained mandibular overdentures, some forces that are by far more powerful are entered to the mandibular implant, which minimize the probability of atrophy. Unfortunately, most conducted studies on the performance and comparison of implant-retained mandibular overdentures have the disadvantage of focusing on comparison of the two first designs in terms of assessing the superiority of either ball or bar system. In a study by ASSUNÇÃO et al, who investigated stress distribution induced by posterior functional loads on conventional complete dentures and implant-retained overdentures with different attachment systems using two-dimentional finite elements, it was found that the use of an attachment system increased stress values. Furthermore, the use of splinted implants associated with the bar-clip attachment system favored a lower stress distribution over the supporting tissue than the unsplinted implants with an O-ring abutment to retain the manibular overdenture (22). It should be noted that the results of the mentioned study are in accord with our study.

Griffitts et al. reported successful results in clinical application of mini dental implants; the authors claimed that mini-dental implants (MDI'S) are a highly successful implant option for patients with poor tolerance to maxillary and mandibular prosthesis. Obviously, an explanation for the difference between the findings of this study and our work is the way of selecting patients (23).

The current study should be introduced as a more complete research in this field. The bottom line is that more studies are needed to investigate these kinds of designs according to the results of our study.

Conclusion

- Destructive forces of the Frost model (pathologic overload window) were seen in none of the designs.
- In this study, the highest amount of strain was observed in protrusive movements (2435 εμ)followed by the figures relating to lateral movements (1668 εμ) in OD-1; both figures are held in mild overload range.
- In OD-2, the highest level of strain was observed in lateral movements (1557 εμ), which is held in the range of mild overload, but in protrusive movements it was only 1179 εμ, held in adaptive window range.

The highest amounts of strain in protrusive and lateral movements were 1023 and 855 εμ in OD-3 A, 980 and 1047 εμ in OD-3 B, 1093 and 907 εμ in OD-4 and 1339 and 937 εμ in OD-5; all these figures are held in the range of the adaptive window.

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