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Stresses generated by two zygomatic implant placement techniques associated with conventional inclined anterior implants

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ABSTRACT

Purpose: To make a comparative evaluation, by means of the finite element method, of the stress generated on supporting tissues and prosthetic system components, using zygomatic implants with the exteriorized and extramaxillary techniques, and different placement positions, associated either with inclined anterior implants, or those without inclination.

Materials and methods: Eight (8) tridimensional models were created to represent the clinical situations being researched, using the dataset of scanned images of an edentulous model. The implants and prosthetic components were photographed on millimeter paper and inserted into Rhinoceros 3D modeling computer software. From the measurements made on the image, the virtual models were made. The application force was distributed on the occlusal surface of the working side of the left maxillary first molar, first and second premolars, and incisal regions of the central incisor, simulating the occlusal load during mastication, in a total of 150 N.

Results: The extramaxillary technique presented considerable variation in increased tension on the prosthesis screws and bone tissue. In the exteriorized technique, the highest tension values occurred in the region of the ridge, and the lowest, on the zygomatic process; the absence of cantilever reduced the stress on bone tissue in almost all regions.

Conclusion: The exteriorized technique was shown to be more favorable to the distribution of stresses on the micro-unit screws and bone tissue, with the model with zygomatic implant placed in the region of the first molar and inclined anterior implant presenting the best results.

1. Introduction

In implant dentistry, the major challenge is to rehabilitate individuals with loss of bone support, especially in the maxillary arch, due to the natural physiological process that occurs after tooth loss. Remarkable changes will occur in the height and width of the alveolar ridge after the extraction of one or several teeth [1]. For rehabilitating these areas, one of the options is to use bone grafts, either with autogenous, homogenous, heterogenous, or alloplastic bone and growth factors [2,3].

The technique of using zygomatic implants has also been as a possibility for the more rapid treatment of atrophic areas, with less morbidity when compared with the use of bone grafts [4]. When well indicated, zygomatic implants have a high success rate [5–7], and immediate loading may be used, optimizing the final time for delivery of the dental prosthesis and presenting a high level of patient satisfaction [8–10].

Four types of zygomatic implant placement techniques have been described, with the most up-to-date being the exteriorized and extramaxillary types [11]. The advantages of these two types are that the zygomatic implants, differently form the other techniques, are placed external to the maxillary sinus, prevent possible conditions of sinusitis, the main complication in this type of therapy [6].

Inclined implants are also indicated for the treatment of atrophic maxillae. In the surgical technique denominated M − 4 only 4 inclined conventional implants are used, and it is possible to rehabilitate individuals without the need for grafts in the maxilla [12].

Atrophic maxillary rehabilitation with zygomatic implants requires the combination of a minimum of 4 implants; 2 may be straight, conventional implants and 2, unilateral zygomatic implants; or 2 zygomatic implants on each side. Selecting the approach will depend on the degree of bone resorption of the maxilla. In daily clinical practice, this resorption may have occurred to such an extent that in some cases, inclination of the anterior implants may be combined with the apex directed 30° towards the lateral paranasal bone of the pyriform aperture [13], with placement of posterior zygomatic implants, which is a

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technique that has not yet been evaluated.

Thus, the aim of this study was to verify, by means of the Finite Element Method, which type of surgical approach could provide better distribution of the stresses and implant stability in the maxilla, and on the zygomatic bone; and compare the exteriorized technique with the extramaxillary type, associated with inclination of the conventional anterior implants.

2. Materials and methods

In the posterior region, was used internal hexagon zygomatic implant of 4.0 × 42.5 mm (Titanium Cortical Screw Master Zigomax 4.0 × 42.5 mm - Conexão Sistemas de Prótese Ltda, São Paulo, Brazil).

In the anterior region, a morse cone implant 3,5 × 10 mm was used (Flash HI Porous NP 3.5 × 10 mm - Conexão Sistema de Prótese Ltda, São Paulo, Brazil).

With the aid of a universal analog pachymeter with 0.05 mm precision (Mitutoyo, São Paulo, Brazil), the implant measurements were obtained. The implants were photographed on millimeter paper, and by means of the Rhinoceros 3D modeling computer software (Robert MCNell & Associados, USA, Seattle, WA), the virtual models were created.

The same steps were used for fabricating the prosthetic components.

For the straight anterior implants, straight micro-unit abutments with 2.5 mm collar; and for the inclined implants, micro-unit abutments angled at 17° with 3.5 mm collar (Conexão Sistema de Prótese Ltda, São Paulo, Brazil) were used. For the zygomatic implants, micro-unit abutments angled at 30° with 3 mm collar (Conexão Sistema de Prótese Ltda, São Paulo, Brazil) were used.

For an assembly with the correct relations of the components on the implants, wear on the implant was performed with a mandril disc, and the relationship of the position between the parts within the implants was studied (Fig. 1).

To make the virtual model of the maxilla, an edentulous model of the middle third of the face with bilaterally pneumatized maxillary sinuses was used, obtained by means of prototyping (Nacional Ossos, São Paulo, Brazil). This was scanned with a 3D laser scanner (Nextengine HD, Santa Monica, USA).

The models were saved in STL (Stereolithography, 3D Systems, Rock Hill, USA) format, for later processing. The use of 3D scanners for obtaining geometric models in Dentistry has previously been documented [14–17].

After this, the images were imported into the Solidworks 2014 software (Dassault Systems, Solidworks Corps, USA), for editing and preparing the virtual models.

The 3D scanner software reconstructed the model with a network of polygonal surfaces. These polygons were exclusively triangular and flat, and to define a model with adequate precision, dozens or hundreds of thousands of polygons are sometimes necessary. However, the majority of CAD type software programs for editing models, such as Solidworks, do not accept the importation of hundreds of thousands of surfaces. Simply diminishing the number of polygons would result in great distortion of the model. To resolve this problem, an importation supplement of Solidworks called “Scanto 3D” was used. With this, it was possible to transform the polygons into surfaces of the NURBS (Non Uniform Rational Basis Splines) type, for generating solid models, so that these surfaces had the capacity to be curves and register geometrical details on the face itself, thus allowing drastic reduction in the number of surfaces necessary, without compromising the precision of the model.

Eight (8) model were created to represent the clinical situations to be researched. Table 1 describes the zygomatic implants in position; technique used, and the morse cone implants with inclination. Table 2 indicates the properties used of each component of the models.

The quality of the mesh and consequently the number of elements has a great influence on the result. In this sense, a large quantity of elements was used in order to seek a well refined mesh. Moreover, to minimize possible numerical errors, a similar mesh was used in the 8 models. The mean number of nodes in each model was 10, 605, 420 and the mean number of elements, 7,612,999. The same could be said of the loading and displacement conditions. Table 3 indicates the quantity of nodes and elements in each model.

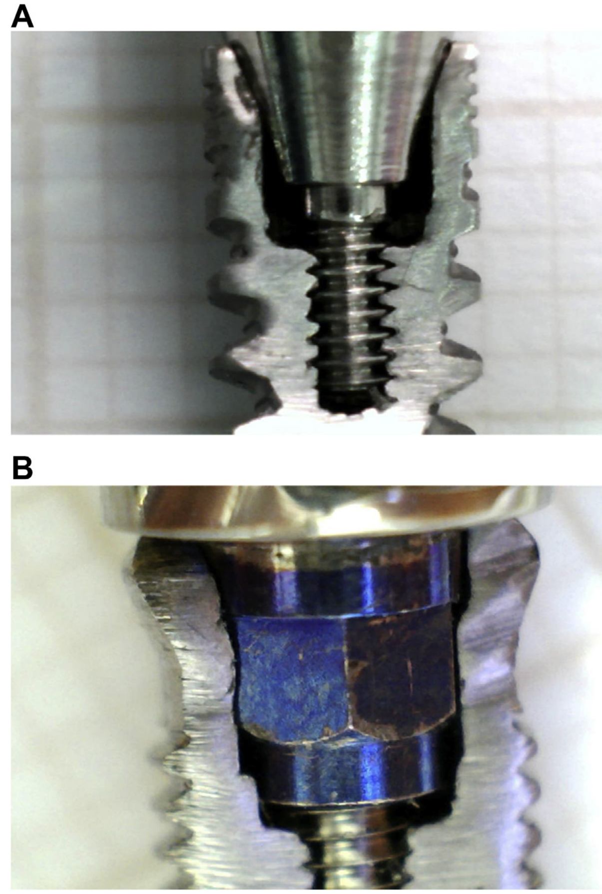

Fig. 1. A: Straight micro-unit abutment with 2.5 mm collar, screw-retained on morse cone implant, B: Micro-unit abutment angled at 30° with 3 mm collar, screw-retained on zygomatic implant.

After discretization into finite elements, the contour conditions were inserted (restriction of movement and occlusal load).

Fig. 2 illustrates the restrictions of movements on the bone ridge of the model. The application force was distributed on the occlusal surface of the working side of the left maxillary first molar, left first premolar, left and second premolar and incisal regions of the central incisor, simulating the occlusal load during mastication, in a total of 150 N (Fig. 3).

The simplifications adopted in this study were: plane state of stress, behavior of material considered linearly elastic, isotropic, loading distributed on surface of dental prosthesis/crown and restriction of displacement at the base of the cortical bone in directions x, y and z.

For pre-processing, processing and readout of results, the *software* Ansys (Ansys Inc, USA, Canonsburg, PA) was used. For stress distribution analysis, the Von Mises criterion of equivalent stresses was used.

3. Results

3.1. Von Mises analysis of stress on screws

Table 4 and Fig. 4 demonstrate the values of stress on fixation mini-screws of dental prostheses in the different models. M5 was observed to present the highest stress on the screws, and M4 presented the lowest stress.