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Linear and Angular Deviations of Implants Placed in Experimental Casts with Stereolithographic Drill Guides Fixed by O'ring Ortho Implant Devices

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The aim of this study was to evaluate whether the introduction of a device, resulting from the combination of an o'ring attachment with an orthodontic implant (o'ring ortho implant, O'ROI), to affix the surgical template of CAD/CAM-guided implant surgery contribute to minimizing the deviations in the position and inclination of implants at the time of their placement. Ten models simulating bone tissue were fabricated and randomly divided into 2 groups: 5 with the scanning and surgical template of the usual technique, representing the Control Group (C), and 5 with scanning and surgical templates fixed by o'ring ortho implants (O'ROI), representing the Test Group (T). Forty implants measuring 4x11 mm were placed in the groups, using the respective templates. The results were evaluated by the fusion of CT images of the planned and placed implants. The locations and axes were compared. There were no statistically significant differences for the angular (Tukey's test $F = 1.06$ and $p = 0.3124$) and linear (ANOVA $F = 2.54$ and $p = 0.11$) deviations. However, the angular values of Group T showed a lower standard deviation in comparison with those of Group C. The use of o'ring ortho implants (O'ROI) is able to minimize the angular and linear deviation of implants at the time of their placement.

Key Words: dental implants, computer-assisted surgery, computed tomography.

Introduction

Research in oral implantology has led to successful and predictable restorative options for partially as well as completely edentulous patients (1,2).

In spite of the advancements, limitations are commonly found in the process of rehabilitating dental arches with implants (3,4). Difficulties arise right from diagnosis to the surgical stage of placing the implants. These are related to the patient's movements during CT scanning or surgery, restricted visualization of the operative field and transfer of the planning performed based on radiographs or tomograph scans to the oral cavity (3,5,6).

Guided surgery is a significant advancement in implant dentistry that enables interdisciplinary activity, drastically reduces surgical time and makes the procedure minimally invasive, flapless, with less bleeding, less discomfort and better recovery and healing. In addition, it allows the occlusal scheme, esthetics and better function intended for the future denture to be transferred to the surgical field. When well conducted, it favors a reduction in the risk of complications regarding mandibular nerve damage, sinus perforations, fenestrations or dehiscences and the possibility of immediate placement, at least, of the temporary denture. These are important advancements and strong points of the guided procedures for implant placement (4,5,7,8).

The benefits and risks of guided surgery have been widely reported and discussed in the literature (4,7). Nevertheless, deviations in the position of planned and placed implants have usually been reported in studies assessing this technique (3,9,10). These deviations increase the risks of fenestrations and damage to noble structures, in addition to making immediate placement of the denture impossible because of the difficulty of adapting it to the implants, which implicates in the need of large occlusal adjustments. Thus, the main advantages of the procedure are eliminated (3,11).

The deviations observed between planned and placed implants reflect the sum of errors that occur right from data collection by tomography, with incorrect position of the radiographic guide, in CAD/CAM modeling for obtaining the guide, precision of the placement of stainless steel guide tubes, and during the surgery with positioning and fixation of the guide to bone tissue (3,9).

The major disadvantage of some surgical guides is the absence of stability in edentulous patient, particularly when the guide is supported only by the remaining soft tissue. Intraoral fixed points of reference (mini implants or temporary implants) could avoid possible inaccuracies and allow a precise and stable placement of radiographic and surgical guides in the presurgical diagnostic stage and during surgery. Then, if adequate support of the guide is provided, precise and efficient surgeries can be performed (12).

In the search for greater accuracy, researchers have used temporary implants to allow rigid support and/or retention of the surgical guide (12). Others (12-15) have used a computer-aided three-dimensional planning protocol in combination with previously placed mini-implants and computer-aided design/computer-assisted manufacture (CAD/CAM) technology to restore completely edentulous patients. Mini-implants were used to establish a setup for computerized tomographic imaging and a surgical template.

The null hypothesis tested in the present study was that the use of o'ring ortho implants for the retention and fixation of scanning and surgical templates could help minimizing deviations in the placement of implants by means of guided surgery.

Material and Methods

In order to conduct this *in vitro* research, a material named BONECRYL® with radiopacity (1525 HU-Hounsfield Units) and hardness similar to that of dense bone tissue was developed and patented by Novellino (2010) (USP Innovation Agency) at the Brazilian National Institute of Industry Property (INPI). This material was developed to simulate jawbone for research purposes and for student's education in implantology. It resulted from a mixture of 25 g of methylethyl methacrylate (Jet self-polymerizing acrylic; Artigos Odontológicos Clássico Ltda., São Paulo, SP, Brazil), 75 g of bone meal (West Garden; Agrofor Comércio e Indútria Ltda, Poços de Caldas, MG, Brazil) and sufficient methyl methacrylate monomer to wet the mixture (Jet self-polymerizing acrylic; Artigos Odontológicos Clássico Ltda.). Bone meal results from the burning and crushing of remains of animals slaughtered for meat and leather, and is used as a fertilizer.

Ten identical completely edentulous maxillary casts were fabricated from BONECRYL® using the same casting mold and were randomly divided into two groups: Group C (control) and Group T (test) (Fig. 1). The models received a 2-mm-thick layer of silicone (Pesilox Fixtudo; Adespec Adesivos Especiais S/A, Taboão da Serra, SP, Brazil) to simulate the mucosa.

An o'ring ortho implant device (O'ROI) (Conexão Sistemas de Prótese Ltda., Arujá, SP, Brazil) was developed for this study, resulting from the combination of an orthodontic implant and an o'ring attachment (Fig. 2A), for the purpose of retaining the scanning and surgical templates only in Group T. The surgical templates were also retained by means of the usual horizontal stabilization pins. Each model in Group T received 3 O'ROIs in a triangular disposition in the arch, and in sites that would not interfere in the placement of the planned implants (Fig. 1). To ensure that the axes

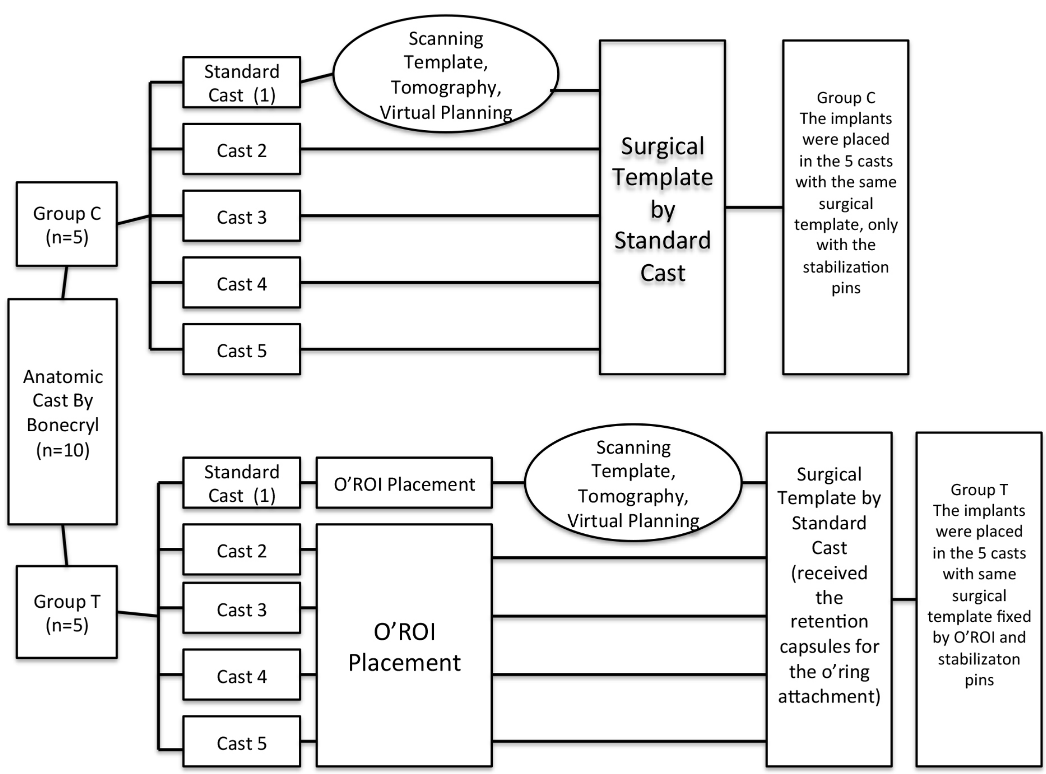

Figure 1. Scheme of division of models and sequence for each group.

and positions of the 3 O'ROIs of the standard model were reproduced in all the Group T models, a specific acrylic resin guide with metal orientation tubes was fabricated with the aid of a surveyor, just for this purpose.

As demonstrated in Figure 1, a model (standard) was chosen in each group (C and T) to receive the scanning guide, to be scanned, to be planned (Implant Viewer; Anne Solutions, São Paulo, SP, Brazil), and based on this plan, the surgical template was fabricated. The scanning template of T group received the retention capsules for the o'ring attachment, by using acrylic resin to fix them directly onto the standard cast. The two standard models (C and T) were scanned (I- Cat, I-Cat Imaging Sciences, Hatfield, PA, USA) with double-scan technique; that is to say, a scan with the scanning template in position on the model (only laid over the cast in Group C and fixed by the o'rings in Group T) and a scan of the scanning template only. It was not necessary to standardize the position of models for the initial e final scanning, since the superimpositions were based on the outlines of identical models. With the data obtained similar virtual planning was performed for Groups C and T with implants in the regions of teeth 16, 13, 23 and 26. The data were transferred to a milling center (Artis, Brasília, DF, Brazil) to fabricate the stereolithography (SLA) surgical template via a CAD/CAM procedure, with the implant positioning sleeves cemented in the surgical template for each group (C and T).

With a kit of special surgical drills for guided surgery (SliceGuide; Conexão Sistemas de Prótese Ltda.), the surgeries were performed for placement of the 4 implants in each model of each group. In Group C the virtually planned guided surgery was performed in the conventional manner (1), only with fixation of the surgical guide by means of horizontal stabilization pins. In the T group models, as

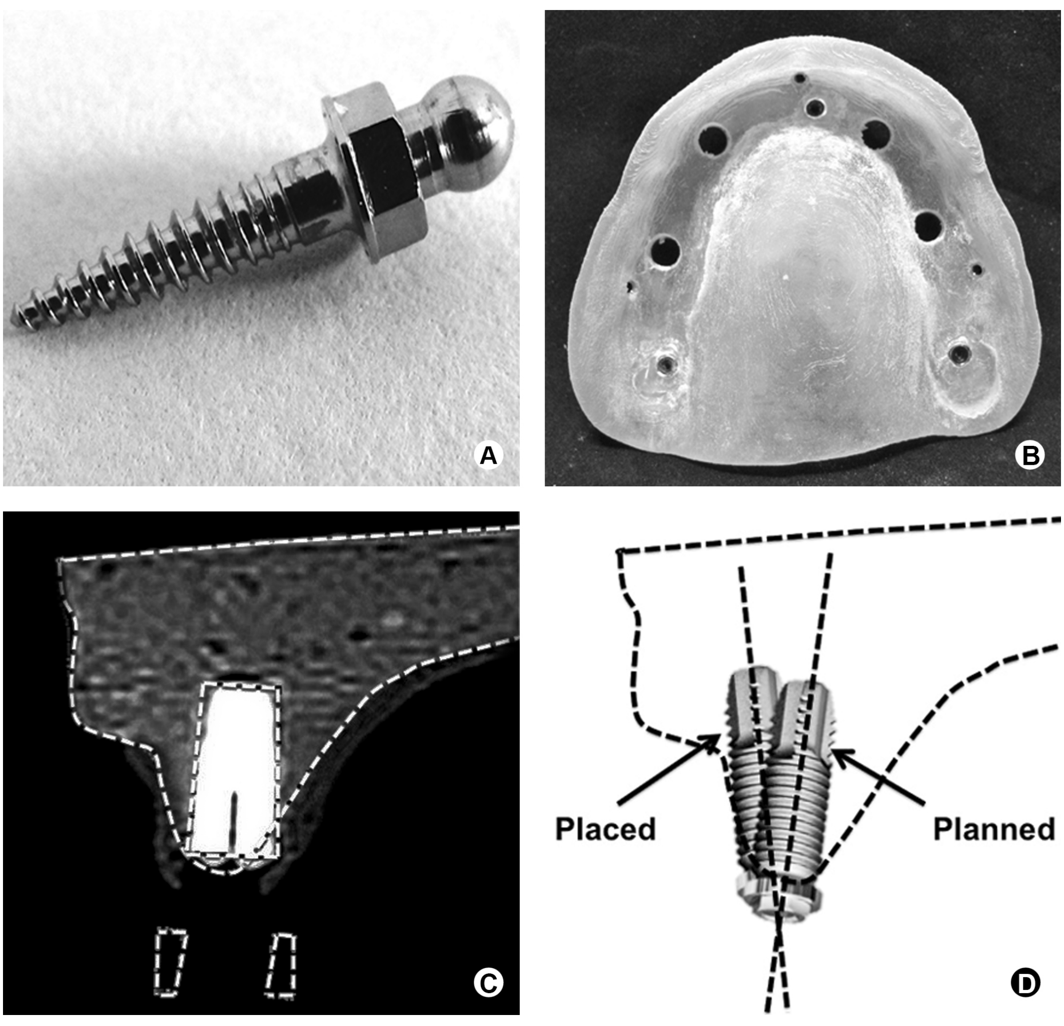

Figure 2. A: Ortho implant associated with o'ring attachment. In models of group T (test), they were used to hold the radiographic and surgical templates. B: Surgical template with o'ring house capsule - Group T - internal view. The four larger holes guide the drilling and implant placement. C: Planned and placed implant at the superimposed of initial and final CT scans. Note the dotted line over the cast image, it is the silhouette of initial CT with the planned implant. D: Placed and planned implants and the cast silhouette. There is an angular difference (dotted line in the center of each implant) and linear at the apex and cervical point of the implants.

occurred with the scanning template, the T group surgical template received 3 capsules of the o'ring attachment (Fig. 2B) but it was also fixed by horizontal pins and implant placement was performed in the same way as it was done in Group C.

External hex implants measuring 4.0 x 11.5 mm (Conexão Sistemas de Prótese Ltda.) were used. The order of implant placement followed a diagonal sequence for better stabilization of the template on the model, that is 26, 13,16 and 23.

The precision of a guided procedure is defined by the deviation in position or angulation of the planned compared with the final result (9). This principle was used to obtain the results. The silhouettes (outlines) of the virtual planning made for Groups C and T were superimposed on the final scan images of each model, in the respective groups, obtained after implant placement. Correct superimposition of the silhouettes with the final scan images was obtained by means of coincidence of the dihedral and trihedral margins of the models. (Fig. 2C).

Two points were determined for each implant: one in the center of the implant neck and the other in the center of the apex. Using the specific tools in the virtual planning program (Implant Viewer; Anne Solutions) linear and angular measurements were taken to compare the position of each virtually planned implant with that of the placed implant (Fig. 2D).

Statistical analysis of the data was performed in two stages: one for linear deviations between the planned and placed, and the other for angular discrepancies. ANOVA and Tukey's tests were used and the significance level was set at 5%.

Results

The results for linear deviations showed there was no statistically significant difference between Groups C and T (F= 2.54 and p=0.11), with means of 1.86 mm for Group C and 2.21 mm for Group T. However, the neck and apex points presented significant statistically difference (F = 28.86 and p = 0.000047), with deviation at the apex point (2.302 mm) being greater than at the neck point (1.770 mm). Averages for linear deviations at the neck and the apex points were greater in Group T (1.97 mm and 2.5 mm) than in Group C (1.6 mm, 2.15 mm) and the analysis of the averages of the interaction of linear deviations at the neck and apex points *vs.* technique (group C and T) revealed no statistically significant difference (F= 0.05 and p= 0.17) (Tukey 5% = 0.37) (Table 1).

As regards angular deviations, the ANOVA test indicated no statistically significant differences between the groups (F= 1.06 and p=0.31), with means of 6.15º for Group C and 5.2º for Group T. Although there was statistically significant difference between the implants (16, 13, 23 and 26) (F= 4.49 and p = 0.009) (Tukey 5% = 3.54), the values for each implant were more homogeneous in Group T than C, and there was a smaller standard deviation for the test Group (T). The values of the angular deviations for the Control and Test group for the implant at region 16 were 1.4° and 5.4°, at region 13 were 10.8° and 4.8°, at region 23 were 8.8° and 4.6°, at region 26 were 3.6° and 6°, respectively.

Discussion

The results of the present study showed that the values obtained for the linear and angular deviations between the planned and placed implants were close to the values found in similar investigations (4,5,16).

Mean angular values of 6.15° and 5.2° for Groups C and T, respectively were very close to those of other authors (4,5,16-19), who found mean values of 3.0° to 7.9° for angular deviation (20).

Angular deviations close to these values are expected when this technique is used, and must be considered when one intends performing an implant placement procedure with SLA templates (3-5,9-11,16-19,21-24). Devices that guide the drills and that adapt to the metal sleeves are 0.2 mm wider than the drills diameter, thus allowing an angular deviation until 5° (1). Angular deviation is always expected, and it is therefore necessary to determine a safety margin for performing this procedure without risks. As reported by Vercruyssen et al. (3), the maximal deviation ever recognized should be taken into account to determine which safety zone should be respected at surgery (3,21,23).

Many authors agree that there will always be deviations, as they are related to cumulative errors that may occur at various stages of the process when a guided surgical procedure is performed, for example during CT scanning, virtual planning, stereolithographic process of surgical template fabrication, positioning of metal sleeves and the surgical phase (3,9,17,20,25).

The results of the present study showed no statistically significant difference between the linear and angular

Table 1. Tukey's test for interaction neck/apex points vs technique (C and T Group)

Residue analysis of variance	0.1957
Probability level	5%
Number of averages compared	4
Number of data by average	20
Degrees of Freedom of residue	32
q value (5%) for 4 averages and 32 degrees of freedom	3.784
Tukey's critical value	0.37431

measurements between the groups. Nevertheless, although the differences between the angular deviations were not statistically significant, they could be analyzed from another aspect, making it possible to collect interesting information. Data in Table 2 show that the implants of Group T presented values that were closer to each other; one verifies that implant 23 presented the lowest value (4.6°) and 26, the highest (6°). Whereas Group C presented very discrepant mean values: implant 16 with the lowest value (1.4°) and 13, (10.8°), with the highest value.

This way, the mean angular differences among the implants were lower for Group T, although there was no statistically significant difference between the groups, suggesting that the o'ring ortho implants (O'ROI) had favored better stability and fixation of the surgical template, minimizing its displacement.

From this aspect, however, evaluating the linear deviation between the implants, the one located in the region of tooth 23 presented the highest mean linear deviation (2.67 mm). This could be related to the order of perforation and placement of the implants. We always began placement with implant 26, followed by implant 13, 16 and concluding with implant 23. Thus, fixation of the surgical guide obtained with implant mounts, in spite of the horizontal fixation or support and retention provided by the o'ring ortho implants (O'ROI), may have favored displacement of the guide to the side of the first implant, generating this distortion.

Although there are limitations to the use of the o'ring ortho implant (O'ROI) for the retention and fixation of templates due to fixation of the o'ring capsule, it may be used to obtain better results in completely edentulous patients, with the additional possibility of the scanning template being used as a provisional denture in the pre-surgical period.

Table 2. Angular and linear deviations

Angular deviations of implants in each group		
Implants	Control Group	Test Group
16	1.4°	5.4°
13	10.8°	4.8°
23	8.8°	4.6°
26	3.6°	6°

Linear deviation means in both groups	
Implants	Distance
16	1.7 mm
13	1.9 mm
23	2.6 mm
26	1.8 mm

The disadvantage of the need of two procedures (O'ROI placement and dental implant placement) is minimized due to the type of implant used (O'ROI). The orthodontic mini implants diameter and length have greatly reduced and their placement dispensing opening mucoperiosteal flap. The procedure can be performed without the need for preoperative medication, and is of little morbidity. The benefits of using these mini-implants in the retention of the template (CT and surgery) as well as the retention of a temporary prosthesis outweigh the disadvantages inherent in the additional procedure.

It is difficult to compare the outcomes of this research with those of previous ones that used mini-implants as a fixed reference aid in the retention and stabilization of scanning and surgical templates because two of the three studies found in the literature were case reports (12,13) and the other was a study that assessed another method using guided surgery without a stereolithographic surgical guide (14). In this latter research, the technique used is a kind of navigation system and the angular average was 2.8 degrees ± 2.2 degrees to 5.2 degrees ahead of average obtained in this research in the test group.

In spite of the limitations of an *in vitro* study, the use of devices for the support and retention of scanning and surgical templates may be useful in the reduction of angular and linear deviations commonly found in guided procedures for implant placement. Further researches, both laboratory and clinical trials, using similar methodologies are required to validate the use of this modified technique.

In conclusion, this study failed to reject the null hypothesis that support and retention devices for scanning and surgical templates, such as the o'ring ortho implant, may be useful in the reduction of linear and angular deviations found in conventional guided surgeries.

Resumo

O objetivo deste estudo foi avaliar se a introdução de um dispositivo resultante da combinação de um encaixe o'ring a um ortoimplante (*o'ring ortho implant*) nas guias da técnica de cirurgia guiada convencional, contribui para minimizar os desvios da posição e inclinação de implantes, no momento da sua colocação. Foram confeccionados 10 modelos simulando tecido ósseo, divididos aleatoriamente em 2 grupos: 5 com a guia tomográfica e cirúrgica da técnica usual, representando o grupo controle (C), e 5 com as guias fixadas a *o'ring ortho implants*, representando o grupo experimental (T). Quarenta implantes de 4 x11 mm foram instalados nos grupos, usando as respectivas guias tomográficas e cirúrgicas. A avaliação dos resultados foi realizada pela sobreposição dos planejamentos virtuais, derivados de tomografias computadorizadas pré-cirúrgicas, com as realizadas após a colocação dos implantes. Não houve diferenças estatisticamente significantes para os desvios angulares (Teste Tukey F = 1,06 e p = 0, 3124) e lineares (Teste ANOVA F = 2,54 e p = 0,11). No entanto, os valores angulares do grupo T mostraram menor desvio padrão em relação aos do grupo C. O uso de *o'ring ortho implants* pode minimizar as alterações de posicionamento dos implantes no momento

da sua colocação, beneficiando a técnica da cirurgia virtual guiada usual.

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