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Biomechanical Analysis of Implant Assisted-Overdentures with Variations in the Attachments Systems

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Abstract

The aim of this study was to assess the stress patterns on the peri-implant zone and residual alveolar ridge in different overdenture attachment system designs by the photoelasticity method. Four attachments systems were tested: O-ring, ERA, Bar-clip, and Bar-clip/O-ring association. The prostheses were loaded with 100 N in five pre-determined points and the photoelastic model was evaluated by a circular polariscope. The anterior load, O-ring, and ERA showed better stress distribution in relation to the bars systems, which presented stress levels surrounding implants. The molar load, Bar-clip/O-ring association, presented the biggest stress concentration on the peri-implant region in relation to the others. When the second molar was loaded, there was a concentration of stress in the alveolar ridge in all situations analyzed. Within the limitation of this "*in vitro*" study, it could be concluded that there were biomechanical differences among the attachments systems analyzed, principally between isolated and the bars systems. The O-ring showed better stress distribution and the Bar-clip/O-ring showed higher stress concentration.

Keywords

Dental Implants, Complete Denture, Overdentures

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1. Introduction

Edentulism is considered as a public health problem that affects most of the population [1] and interferes in the quality of life of patients, both physically and psychologically [2]. Furthermore, recent studies suggest that tooth loss affects the intake of nutrients, due to a significant reduction of masticatory efficiency, [3] and could increase the risk for several diseases [4]-[6].

In this sense, dental implants have been used for improving the masticatory capacity in fully edentulous patients, favoring an increase in the quality of life of these patients [7]. Two treatment modalities are widely used for the rehabilitation of fully edentulous patients: overdentures and fixed full-arch prosthesis [8], the indication depends on the individualities of each patient to be rehabilitated [9].

Sometimes, a greater number of implants cannot be installed, thereby limiting the installation of fixed full-arch prosthesis [10]. In these cases, overdentures are indicated due to higher stability and retention than conventional dentures [11]. For this type of rehabilitation treatment, different attachment systems are available: O-ring, ERA, Bar-clip, or associations among the systems [12].

The clinical success and longevity of dental implants are influenced by the stress distribution transferred to implant and surrounding bone [13]. The different attachment systems used in overdentures present different biomechanical characteristics, and can offer risk to osseointegrated implants [14] [15]. *In vitro* studies have analyzed stress distribution in peri-implant bone, avoiding unnecessary risks. However, there is no consensus in the literature about the biomechanical effect of attachment systems that are different for overdentures prosthesis. Thus, the aim of this *in vitro* study is to analyze by the photoelasticity method the stress distribution in peri-implant bone and the alveolar ridge when using different attachment systems for the overdentures. The research hypothesis is that there is no difference in stress distribution among the attachment systems evaluated.

2. Materials and Methods

The model representing an edentulous mandible was duplicated with laboratory silicon (Silibor, ArtigosOdontológicos Clássico Ltda., São Bernardo do Campo, SP, Brazil) to obtain a study model. The model was drilled on the regions of inferior canines and was performed dental implants placement coupled to a parallelometer and fixed with acrylic resin (Duralay, Reliance Denture MgfInc Co., Alsip, IL, USA). Square copings were screwed in the implants and the model was duplicated with silicon impression material to simulate impression transfer. Two implants with external hexagon and regular platform 4.1 mm (φ = 3.75 × 10 mm) were adapted and screwed into the copings (3i, Implant Innovation Inc., Palm Beach Gardens, Florida, EUA). To obtain the photoelastic model, the plaster model was duplicated using photoelastic resin (PL-2 Vishay; Micro-Measurements Group, Inc., Raleigh, NC, USA) to give the impression that the implants were incorporated.

Four models of overdentures with different attachments were assessed (**Figure 1**). The attachment systems used were: Model A: O-ring (O) (Conexão Systems Prosthodontics, São Paulo, SP, Brazil); Model B: ERA (E) (Sterngold Implamed, Attleboro, MA, USA); Model C: Bar-clip (BC) (Conexão Systems Prosthodontics, São Paulo, SP, Brazil) and Model D: Bar-clip associate O-ring (BCO) (Conexão Systems Prosthodontics, São Paulo, SP, Brazil). The bar systems BC and BCO were fabricated under the photoelastic model with 2 mm of distance in the bar/model interface. In the model BCO, the bar was splinted with two distal O-ring attachments (Conexão Systems Prosthodontics, São Paulo, SP, Brazil). The bars were used according the instructions of the LiteCast NiCr metal league supplier (Williams Advanced Materials, Buffalo, NY, USA).

Four overdentures with the same artificial teeth position were made. Tostandardize, the first over denture was duplicated withl aboratory silicone (Silibor, Artigos Odontológicos Clássico Ltda., São Bernardo do Campo, SP, Brazil). This mold allowed the same teeth position and similar thickness of the denture base, respecting the relief for each attachment system.

To simulate the mucosa thickness, 1 mm Coe-Soft (GC América, Alsip, IL, USA) was incorporate over the prosthesis, between the denture base and the photoelastic model. This resilience has a significance influence on stress distribution of the implants and cannot be ignored.

To verify the quality of photoelastic models as well the attachments bar passivity, all of the samples were analyzed on the polariscope to accuse residual stress. At the center of the polariscope, overdentures were loaded with a universal mechanical testing machine (Emic, São José dos Pinhais, PR, Brazil). The axial compressive load was 10 kgf (100N) and 0.5 mm/s applied on the anterior region between the central incisors, posterior region in the mesial fossa region of the second premolar and central fossa of the second molar. Each point was in-

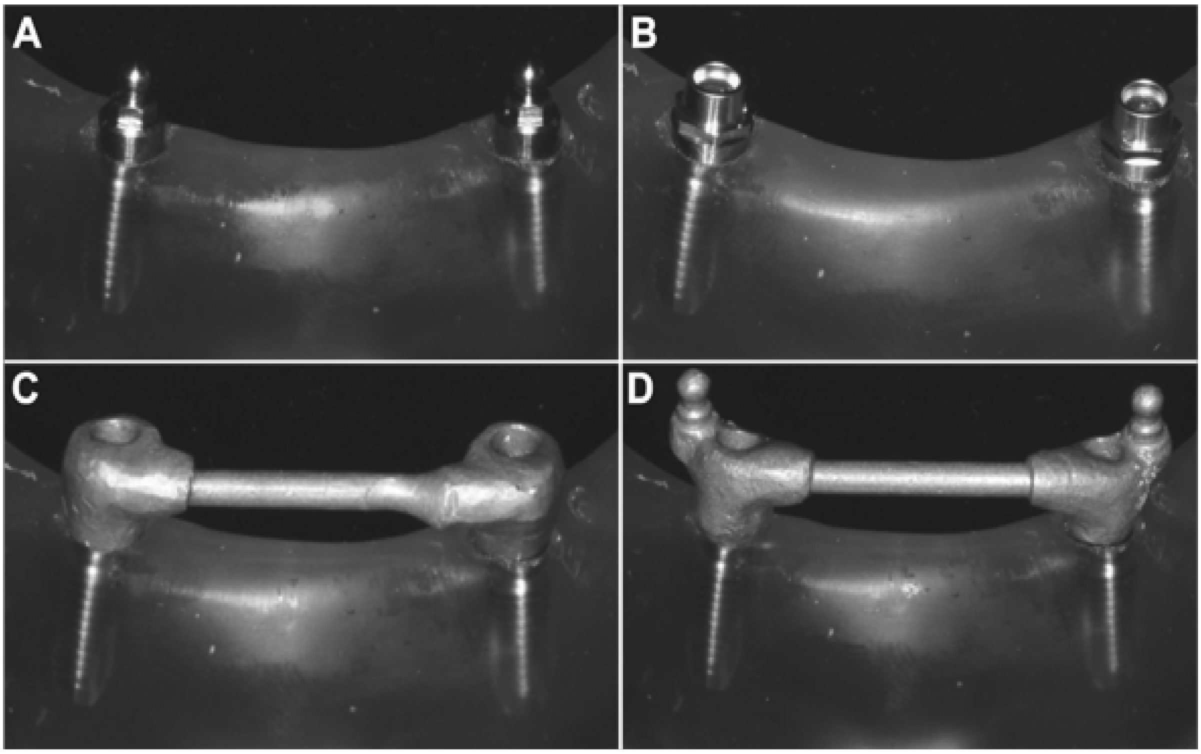

Figure 1. Attachment systems. (A) O-ring; (B) ERA; (C) Bar-clip; (D) Bar-clip/O-ring.

dividually loaded and the stresses patterns for each region were captured by photo (Nikon D70 105 mm macro lens-Nikon Corp, Minato-Ku, Tokyo, Japan) with images obtained at static position. The results were evaluated qualitatively through the counting of isochromatic fringes. The higher the number of fringes, the more stress was concentrated on the region.

3. Results

3.1. Anterior Load

In the present study, a difference between treatments was observed (**Figure 2**). The attachment systems O-ring and ERA transferred part of the stress to the anterior the region of alveolar ridge, while the bar models did not show stress in the anterior alveolar ridge. The apical region of the implants showed a greater number of fringes corresponding to a higher magnitude of stress. However, the bars system exhibited higher stress on the cervical third of the implant. The O-ring attachment exhibited lower numbers of fringes on the apical region of implant followed by the ERA. The anterior load did not show stress in the posterior alveolar ridge in all situations, but the distal alveolar crest region of implants on O-ring attachment showed higher concentrations of stress.

3.2. Premolar Load

After loading on the mesial fossa of second premolar, the anterior alveolar ridge showed lower stress. For all the models, the ipsilateral implants showed higher number of fringes when compared to the contralateral implants. For the bar systems (BC and BCO), the implants showed more number of fringes than the O and E models (**Figure 3**). The model with the O-ring attachment resulted in lower stress on the implants and greater stress on the alveolar posterior ridge. The model ERA attachment exhibited a higher number of fringes in the implants, when compared to the O-ring; however, ERA exhibited a smaller number than the attachment systems BC and BCO. The BC model showed higher stress in the implants and regular distribution on the posterior alveolar ridge, whereas the BCO model showed the highest number of fringes in the implants, but the lowest stress on the alveolar ridge (**Figure 4**).

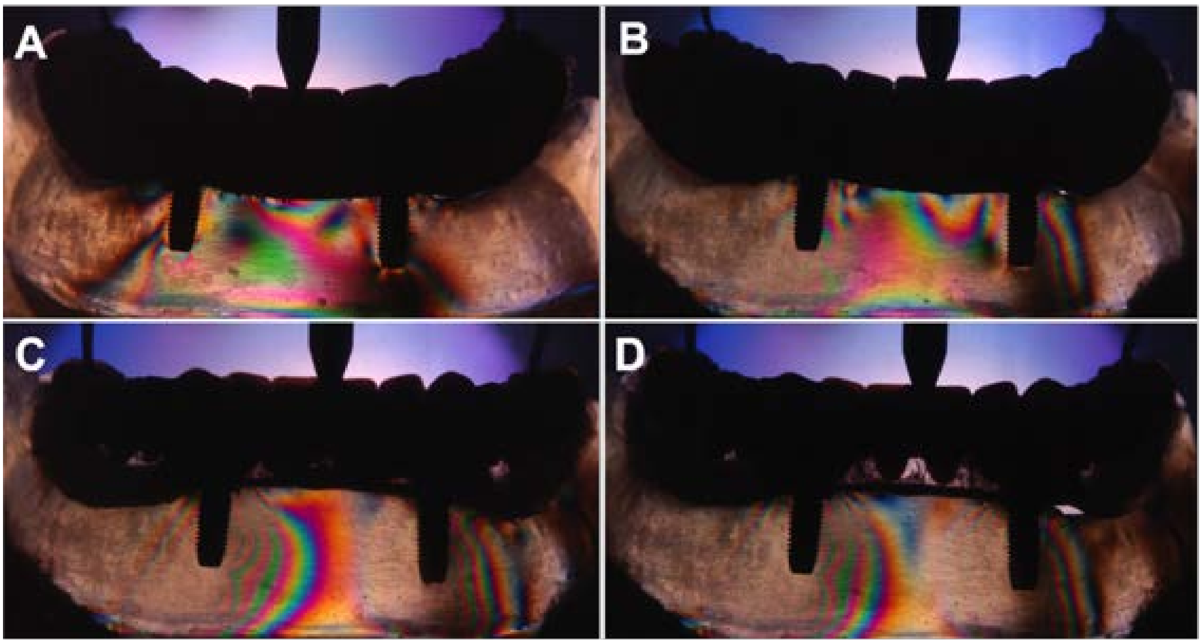

Figure 2. Isochromatic fringes in the anterior support areas.

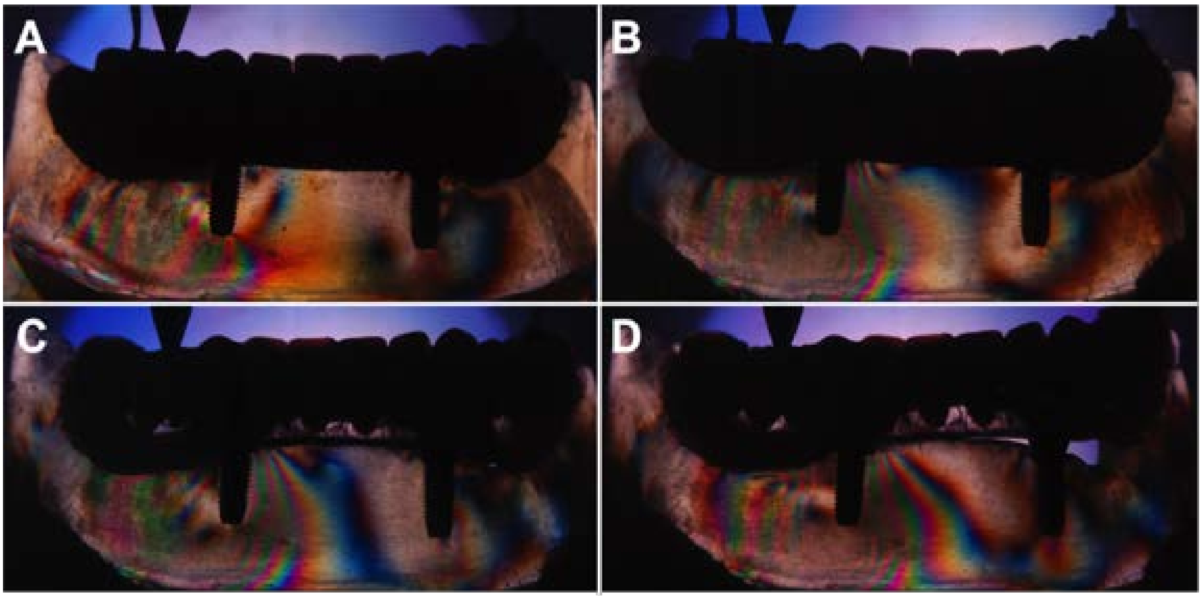

Figure 3. Isochromatic fringes in the anterior support areas on the premolar loading.

3.3. Molar Load

The loading in the molar, stresses were not observed in the anterior ridge. The O-ring model showed few fringe in the implant when compared to the ERA attachment system. For the models with bar (BC and BCO), the BCO exhibited the higher number of fringes on implant region. Due to lower stress on implants, the O-ring attachment showed higher stress on the posterior alveolar ridge, followed by ERA, BC, and BCO models, which showed lowest number of fringes on alveolar ridge (**Figure 5**).

4. Discussion

According to the McGill consensus [16], the use of two implants for overdentures should become the first choice of treatment for an edentulous mandible, improving the quality of life of patients [17]. The bone preservation depends on the occlusal forces that are transmitted to the bone; it is preferable that the attachment systems provide greater balance in stress distribution [18].

However, there is no consensus about the best type of attachment system for overdentures implant retained. Some authors [15] [19] showed no clinical difference among the attachments systems over the time. However, most studies evaluated different retention systems clinically, comparing only the ball and bar attachment systems.

The choice of attachment systems for overdentures depends on several factors, among them retention, which is considered an important criterion, but also should take into consideration stress distribution [20]. In this sense, biomechanical analysis as the photoelastic method has been used to elucidate possible doubts relative to stress distribution [21]. The hypothesis tested by study was rejected, since it observed difference in stress distribution among different attachment systems in overdentures.

This different results in the attachment systems have been reported by others authors [20] [22] [23]. The

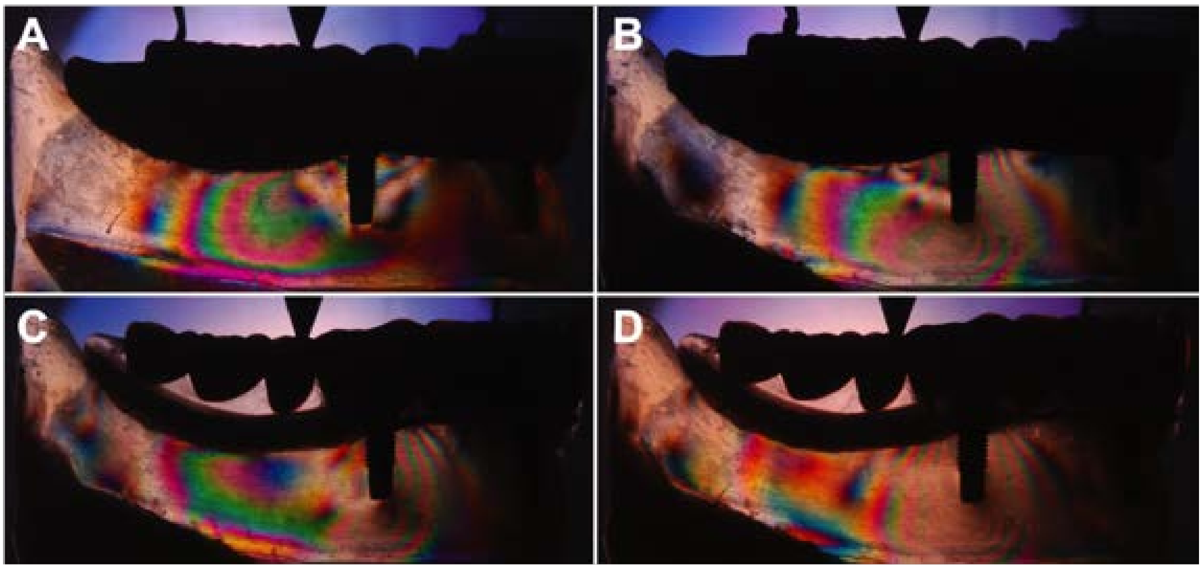

Figure 4. Isochromatic fringes in stress distribution in the anterior/posterior support areas on the premolar loading.

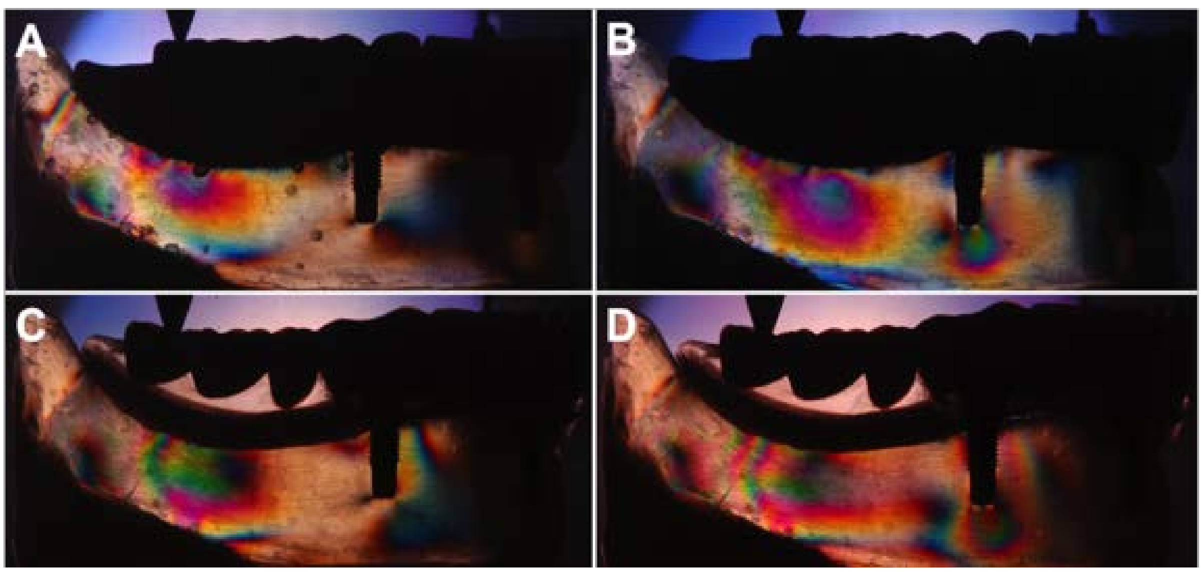

Figure 5. Isochromatic fringes in stress distribution in the anterior/posterior support areas on the molar loading.

unsplinted attachments, such as the O-rings and ERA attachments, showed better stress distribution along the alveolar ridge and implants [20] [22] [24]. The lower stress observed by O-ring may have been influenced because of the modulus of elasticity of the resilient rubber ring inside the capsule which can absorb part of the load [12].

Overdentures splinted by a bar attachment showed higher stress, including on the contralateral implants [20] [24]. This may be clinically identified, because the implants showed lightly shallower probing depths around the implants compared to that of the bar attachment system [25].

However, some studies reported that the bar attachment system showed more retention for the mandibular overdentures than without bar attachment [26] [27], being indicated for cases with little retention. Moreover, the bar attachment systems need less maintenance in relation to the O-ring attachment [28].

Another factor to be taken into considerations is intermaxillary space for the attachment systems, because is necessary that the minimum space is under the bar, to favor access for cleaning and avoiding what may cause a soft tissue inflammatory response [19].

Considering the influence of stress distribution, the O-ring retention system showed smaller stresses which clip O-ring association. Nevertheless, for this attachment is recommended the parallelism between implants [29] as used in this study, fact that may have influenced for the greater results is in the O-ring model. All isolated systems agree to literature findings [20] [22] [24] that attribute better stress distribution in these situations. The ERA attachment transfers stress for the contralateral implant when the overdentures were in displacement, and this factor can represent important clinical significance during the function.

The association of two attachment systems can be used in cases that are necessary for improving the stability and retention of prosthesis, due to the number or position of the implants. However, stress distribution in the attachment systems is not favorable, as observed in the literature [12].

Although the data compared in this study show different stress distributions across each situation, the clinical decision needs more scientific support, mainly due to the unknown level of physiologically tolerance.

The limitations of this study include the resin used for simulating the bone that presents differences when compared with real tissue [30], and assumes all the structures are isotropic and homogeneous [31]. Thus, the results observed in this studied should be analyzed with caution for each case in particular, it may help clinicians to define the best of attachment systems.

5. Conclusion

Considering the limitations of this study *in vitro* can conclude that the isolated attachment systems are used for more equal distribution when compared to the bar attachment systems that transmit higher stress levels to the peri-implant area.

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Abbreviations

O-ring = (O)
ERA = (E)
Bar-clip = (BC)
Bar-clip associate O-ring = (BCO)