

ORIGINAL ARTICLE

## Stress distribution in implant-supported prosthesis with external and internal implant-abutment connections

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### Abstract

**Objective.** This study aimed to investigate the stress distribution in screwed implant-supported prostheses with different implant-abutment connections by using a photoelastic analysis. **Materials and methods.** Four photoelastic models were fabricated in PL-2 resin and divided according to the implant-abutment connection (external hexagon (EH) and Morse taper (MT) implants (3.75 × 11.5 mm)) and the number crowns (single and 3-unit piece). Models were positioned in a circular polariscope and 100-N axial and oblique (45°) loading were applied in the occlusal surface of the crowns by using a universal testing machine. The stresses were photographically recorded and qualitatively analyzed using software (Adobe Photoshop). **Results.** Under axial loading, the MT implants exhibited a lower number of fringes for single-unit crowns than EH implants, whereas for a 3-unit piece the MT implants showed a higher number of fringes vs EH implants. The oblique loading increased the number of fringes for all groups. **Conclusion.** In conclusion, the MT implant-abutment connection reduced the amount of stress in single-unit crowns, for 3-unit piece crowns the amount of stress was lower using an external hexagon connection. The stress pattern was similar for all groups. Oblique loading promoted a higher stress concentration than axial loading.

**Key Words:** dental implants, biomechanics, fixed prosthesis, photoelastic stress analysis, screw retained

### Introduction

Dental implants have been extensively used to rehabilitate edentulous patients owing to their high success rate. Additionally, increased masticatory efficiency, satisfaction and quality-of-life of several subjects have been reported by means of dental implants [1,2].

Nevertheless, the clinical success or failure of dental implants relies on the way that masticatory loads are transferred and absorbed by the surrounding bone tissue. Several factors such as type of loading, implant-abutment connection, bone-implant interface, implant's surface treatment, quality of prosthesis and bone property might affect the loading transmission to the bone [3–5].

In this way, many configurations of implant-abutment connection have been introduced in order to improve the stress distribution between implant and bone such as internal hexagon, internal octagon and combination of screwed and friction systems (i.e. Morse taper). The Morse taper system has a large contact area and frictional resistance in the implant-abutment interface to provide a stable connection [6,7]. Also, *in vitro* [8–13] and longitudinal clinical studies [14–17] have reported excellent mechanical stability of this type of connection.

Several methods to investigate the stress behavior on the peri-implant bone tissue have been reported. In the current study the photoelastic analysis was used and has been extensively applied in Dentistry [4,5,18–20].

Table I. Studied groups.

Groups	Implant	Implant–abutment connection	Dimensions	Prosthesis
I	Osteofit	External hexagon	3.75 × 11.5 mm	Single
II	Osteofit	External hexagon	3.75 × 11.5 mm	3-unit piece
III	Osteofit	Morse taper	3.75 × 11.5 mm	Single
IV	Osteofit	Morse taper	3.75 × 11.5 mm	3-unit piece

Therefore, the present study aimed to investigate the biomechanical behavior of screwed implant-supported prostheses with different implant–abutment connections in single and 3-unit piece prostheses by using a photoelastic analysis. The research hypothesis was that the Morse taper system showed the lower stress distribution for both crowns (single and 3-unit piece).

### Materials and methods

A metallic matrix (40 × 45 × 10 mm) was fabricated and poured with silicone (Sapeca artesanato, Bauru, São Paulo, Brazil). The space provided by the matrix was filled out with type IV dental stone (Durone, Dentsply, Petrópolis, Rio de Janeiro, Brazil) in order to obtain four models. Models were divided into four groups according to the type of implant–abutment connection and prosthesis, as shown in Table I.

The models in dental stone were perforated to receive the implant replica (Osteofit, Campo Largo, Paraná, Brazil) of each group. The insertion of the implant replicas was standardized by means of a parallelometer (in its long axis). The implant replica was screwed to the corresponding pick-up transfer (Osteofit, Campo Largo, Paraná, Brazil) and inserted into the dental stone block until the platform of the implant replica was in the same level of the upper part of the block. All implant replicas were placed with their long axis perpendicular to the

horizontal plane and fixed with self-polymerized acrylic resin (Duralay, Duralay Reliance Dental, MFG Co., Worth, IC).

The dental stone models with the implant replicas in place were duplicated and a new mold was obtained in which the external hexagon implants and Morse taper implants (Osteofit, Campo Largo, Paraná, Brazil) were placed according to each group. Afterwards, the mold was poured with photoelastic resin (PL-2, Vishay, Micro-Measurements Group, Inc., Raleigh, NC) according to the manufacturer's recommendation. Each set was placed under a pressure of 40 lbf/pol2 to remove internal bubbles.

For Groups I and III, single-unit screwed crowns corresponding to the mandibular second premolar were fabricated. For Groups II and IV, 3-unit screwed crowns corresponding to the mandibular second premolar, first molar and second molar were fabricated. All crowns were fabricated in Nickel-Chromium alloy (Fit Cast –SB Plus, Talladium do Brasil, Curitiba, PR, Brazil) with standardized dimensions. The crowns were screwed in the implants with a torque of 20 N according to the manufacturer's recommendation.

The set was positioned in a circular polariscope and an initial photograph record without load application was performed in order to verify the absence of stress on the photoelastic models. Sequentially, 100-N axial and oblique (45°) loads were applied at different points in

Table II. Number of photoelastic fringes according to the crowns in which the load was applied.

Groups	Axial load crown			Oblique load crown		
	34	35	36	34	35	36
I		3			5	
II	2	0	2	3	2	2
III		1			3	
IV	3	5	3	5	4	4

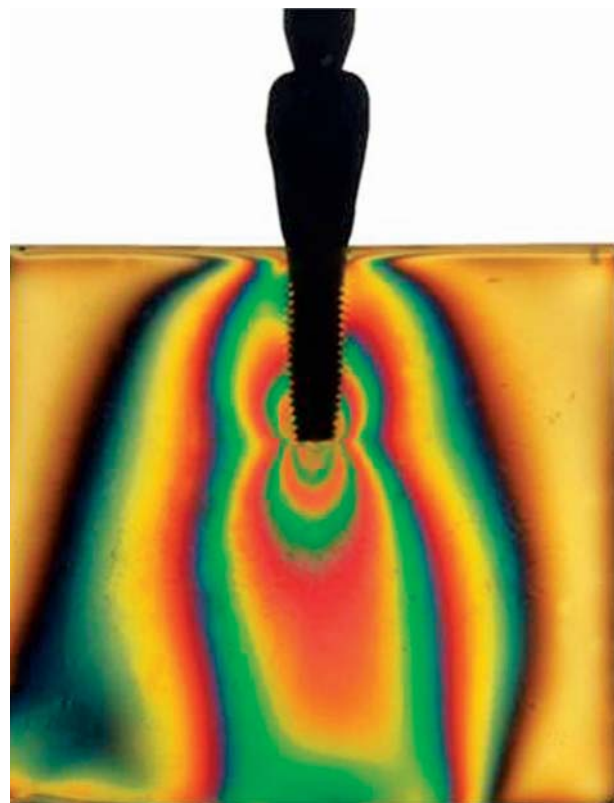


Figure 1. Axial load for Group III.

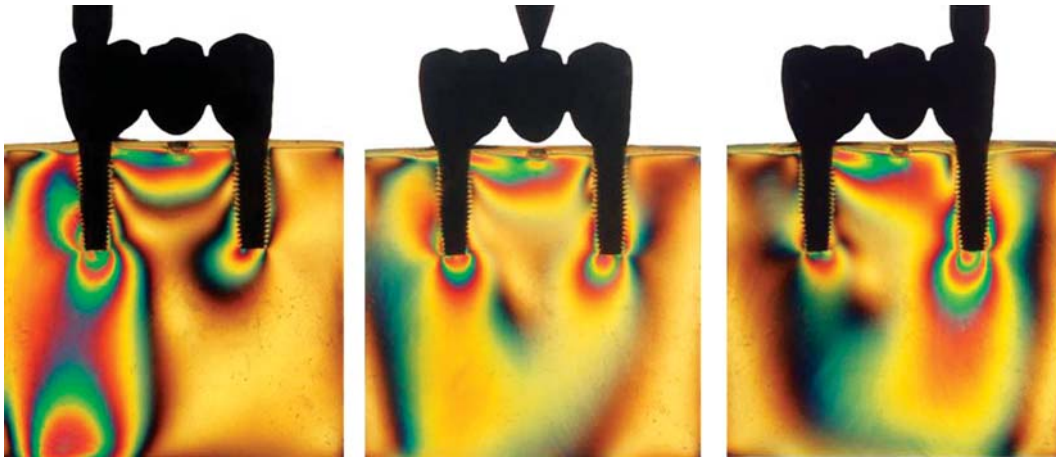


Figure 2. Oblique load for Group III.

three prosthetic elements on a standardized area of the occlusal surface of all crowns individually during 10 s by means of a universal testing machine (EMIC-DL 3000, São José dos Pinhais, Paraná, Brazil). A 45 tilted apparatus was used during oblique loading application.

Data were photographically recorded (Nikon D80, Nikon Corp, Japan) and further analyzed in an image software (Adobe Photoshop CS3, San Jose, CA).

Photograph records of all models were qualitatively analyzed to verify the direction and intensity of stress based on other studies [21].

In this sense, the higher the fringes order (N) and fringes number are, the greater the stress intensity is. Additionally, the closer the fringes are among each other, the higher the stress concentration is.

The analysis was divided according to the number of fringes with high intensity (green–pink transition) and to the stress distribution area. All images were evaluated by the same person.

## Results

### *According to the number of fringes with high intensity (Table II)*

The single-unit crown associated to Morse taper connection (Group III; Figures 1 and 2) showed the lower number of fringes vs external hexagon (Group I; Figures 3 and 4) for both loading conditions. On the other hand, in the case of a 3-unit piece the Morse taper (Group IV; Figures 5 and 6) exhibited the greatest number of fringes. In all conditions, oblique load induced a higher number of fringes when compared to the axial load.

### *According to the fringes concentration area*

Under axial load, high stress concentration was observed on the apex of implants (Figures 1, 3, 5 and 7),

independent groups. The area of stress concentration was greater for groups I and II.

Under oblique load, the stress was placed on the peri-implant bone region and implant apex (Figures 2, 4, 6 and 8). The implant apex exhibited the greatest stress concentration, independent groups.

The groups I (Figure 3), II (Figure 7, axial load applied on mandibular second molar) and IV (Figure 6, oblique load applied on mandibular second

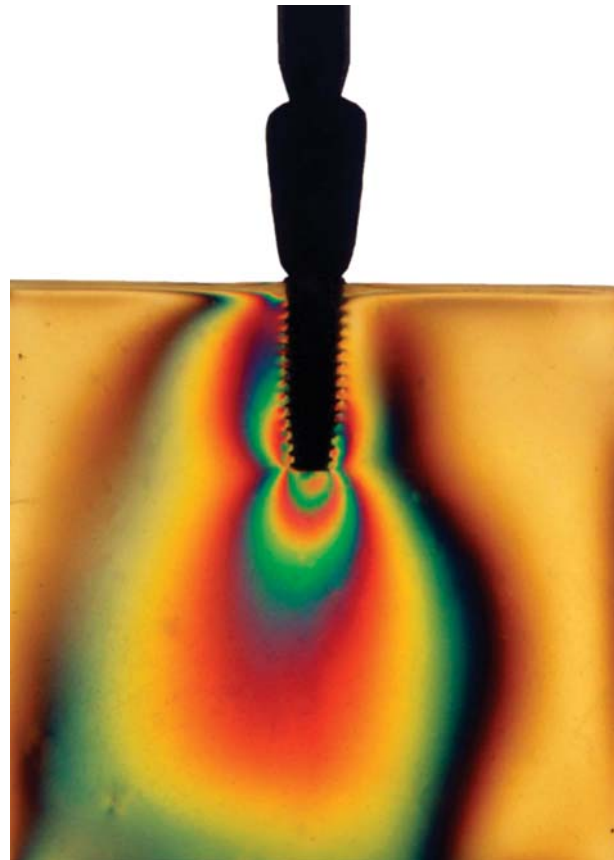


Figure 3. Axial load for Group I.

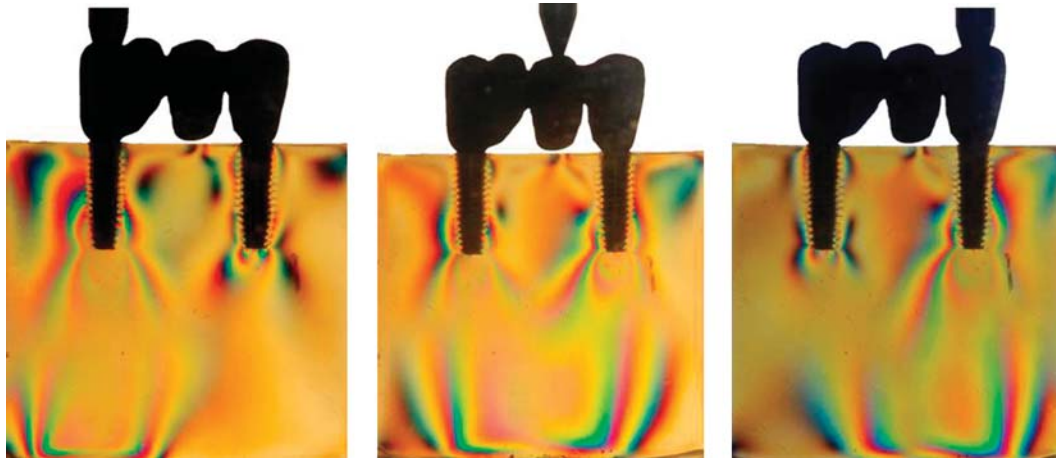


Figure 4. Oblique load for Group I.

premolar) showed increased stress concentration on the implant apex.

### Discussion

The research hypotheses was that the Morse taper system showed the lower stress distribution for both crowns (single and 3-unit piece) was partially accepted. The MT implants (Group III; Figures 1 and 2) exhibited a lower number of fringes for single-unit crowns than EH implants (Group I; Figures 3 and 4). Whereas for a 3-unit piece the MT implants (Group IV; Figures 5 and 6) showed a higher number of fringes vs EH implants (Group II; Figures 7 and 8).

The way that masticatory loads are transmitted and distributed to the bone affects the success rate of dental implants. The loading transmission to the bone might be linked to the type of loading, implant–abutment connection, bone–implant interface, implant’s surface treatment, implant’s diameter and length, quality of prosthesis and bone property [3–7,20].

According to the results of the present study, the type of implant–abutment connection influenced the stress distribution to the bone in single and 3-unit piece implant-supported prostheses. In case of single crown, the Morse taper system (Group III, Figures 1 and 2) had the lower number of fringes vs external hexagon (Group I) for both load conditions (Figures 3 and 4). This is in agreement with previous studies [12,22] which have highlighted the importance of implant–abutment connections on the stress distribution around implants.

Merz et al. [8], Khraisat et al. [10] and Drago and O’Connor [23] also advocated that internal connections provided better stress distribution than external ones. Additionally, Binon [22] stated that internal connections have a more stable interface due to the presence of an intimate contact between the internal

part of the implant with the external part of the abutment, which is in favor with the load distribution, protecting the retention screw.

Furthermore, internal connections present several advantages as reduced vertical force from the implant platform to the upper part of the abutment, lateral load distribution within the implant allowing a better protection of the screw abutment and the presence of a long inner wall that creates a rigid and stable connection resisting to bending moments [11,22].

Although internal connections have many advantages when compared to external connections, several divergent results still exist. Astrand et al. [17] showed similar stress distribution behavior of internal and external connections, while Maeda et al. [13] found difference between the systems just under oblique loading. In our study, an increase in fringes number was observed under oblique loading (Figures 2, 4, 6 and 8) for all conditions.

However, for 3-unit piece the Morse taper connection (Groups IV; Figures 5 and 6) showed a greater number of fringes with high intensity than those

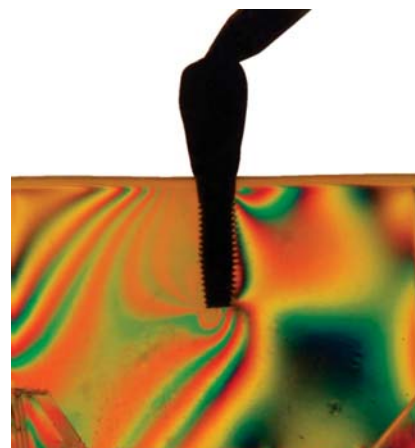


Figure 5. Axial load for Group IV, applied in three different points.



Figure 6. Oblique load for Group IV, applied in three different points.



Figure 7. Axial load for Group II, applied in three different points.



Figure 8. Oblique load for Group II, applied in three different points.

observed for the external hexagon connection (Group II; Figures 7 and 8) in both loading conditions. On the other hand, the groups (I and II) associated to the external hexagon exhibited a more spread area of stress concentration.

These results are in accordance with *in vitro* studies in which Morse taper connection optimizes the biomechanical behavior of single unit prosthesis when compared to external hexagon connection, independent of the inclination of load on the implant-supported prosthesis [8,9,14–16,24].

Possibly when the Morse taper implants were splinted, the stress increased due to the implant's inclination. The absence of a minimum parallelism among implants can affect the stress concentration on the system. Clinically, it is hard to obtain a situation of complete parallelism of the implants. Therefore, the results of the present study indicate the use of an external hexagon in the case on multi-unit piece crowns.

## Conclusion

The type of implant–abutment connection influenced the bone stress level in single and 3-unit piece implant-supported prostheses. The Morse taper connection reduced the amount of stress in single-unit crowns. However, for 3-unit piece crowns the amount of stress was lower using an external hexagon connection.

No significant difference on stress distribution pattern was observed among the groups, independent of prosthesis type and implant–abutment connection. The oblique load induced greater stress concentration and intensity than axial load.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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