INFLUENCE OF RIDGE TYPE ON MANDIBULAR DISTAL EXTENSION REMOVABLE PARTIAL DENTURE

Eduardo Piza Pellizzer, Renato Ferraço, Bianca Piccolotto Tonella, Bruno J. de Cazaes Oliveira, Fabiano Lopes Souza, Rosse M. Falcón-Antenucci

Dental Materials and Prosthodontics Department , Araçatuba School of Dentistry, São Paulo State University, Brazil.

ABSTRACT

The aim of this study was to use photoelastic models to analyze the distribution of stress caused by the incidence of loads on a mandibular distal extension removable partial denture, both on the abutment teeth and on differently shaped residual ridges: distal ascending, descending-ascending, horizontal and distal descending. The best type of retainer and location of the rest on the last abutment tooth were determined for the different types of ridge. Four models were made from photoelastic resin (PL-1 for the teeth and PL-2 for the alveolar ridge), one for each kind of ridge. For each model, 4 removable partial dentures (RPD) were made (16 RPD altogether): T-bar retainer and distal rest, T-bar retainer and mesial rest, circumferential retainer and distal rest, and circumferential retainer and mesial rest. The models were placed on a circular polariscope and a 100 N axial load (point load) was applied to premolars and molars of the RPD. The formation of photoelastic bands was photographed for qualitative analysis. Results showed that the horizontal ridge had better distribution of stress, while the distal descending ridge had greater concentration of stress. The circumferential retainer had greater areas of stress for all types of ridges except the horizontal ridge, where there was no influence related to retainer type. The distribution of stress was similar among the different types of ridges when the rest was mesial or distal to the last abutment tooth, except for the distal descending ridge, where there was greater concentration of stress when the rest was located distally to the last abutment tooth. Thus, it may be concluded that (1) the situation was least favorable for the distal descending ridge and most favorable for the horizontal ridge, (2) the T-bar retainer had more favorable stress distribution, except when the ridge was horizontal, in which case there was no influence in relation to the type of retainer, (3) the location of the rest showed similar behavior in all except the distal descending ridge.

Key words: denture, partial, removable; alveolar process, dental stress analysis.

INFLUÊNCIA DO TIPO DE REBORDO EM PRÓTESE PARCIAL REMOVÍVEL MANDIBULAR DE EXTREMIDADE LIVRE

RESUMO

O objetivo da pesquisa foi analisar, através de modelos fotoelásticos, a distribuição das tensões formadas pela incidência de cargas sobre a prótese parcial removível de extremidade livre mandibular, nos dentes suporte e no rebordo residual nas formas: ascendente distal, descendente-ascendente, horizontal e descendente distal. Nos diferentes tipos de rebordo foi verificado o melhor tipo de grampo e a localização do apoio no ultimo dente suporte da extremidade livre. Foram construídos 4 modelos de resina fotoelástica (PL-1 para os dentes e PL-2 para o rebordo alveolar), um modelo para cada tipo de rebordo. Para cada modelo foram confeccionados 4 próteses parciais removíveis (PPR)(total de 16 PPR): com grampo em barra T e apoio na face distal, com grampo em barra T e conector na mesial, grampo circunferencial e apoio na face distal e grampo circunferencial e apoyo na face mesial. Os modelos foram posicionados em um polariscópio circular e aplicado carga pontuais e axiais de 100 N nos pré-molares e molares das próteses. As franjas formadas foram fotografadas para análise. Os resultados foram analisados de uma forma qualitativa e podemos observar que o rebordo horizontal apresentou uma melhor distribuição das tensões, enquanto o rebordo descendente distal apresentou as maiores concentrações de tensões. O grampo circunferencial apresentou as maiores formações de tensões em todos os tipos de rebordo, exceto no rebordo horizontal, onde não houve influência quanto ao tipo de grampo. Não houve diferença significante entre os tipos de rebordo ao posicionar o apoio na mesial ou distal do último dente suporte, com exceção feita ao rebordo descendente distal, onde se acentuou a concentração de tensões ao posicionar o apoio na distal do último dente. Desse modo, podemos concluir que (1) o rebordo mais desfavorável foi o descendente distal e o mais favorável o horizontal, (2) o grampo em barra T apresentou distribuição de tensões mais favoráveis, com exceção do rebordo horizontal, onde não houve influência quanto ao tipo de grampo, (3) e que a localização do apoio apresentou comportamentos semelhantes, a não ser no rebordo descendente distal.

Palavras chave: prótese parcial removível; rebordo alveolar; análise de tensões.

INTRODUCTION

Removable partial dentures (RPD) play an essential role in treating partly edentulous patients with large toothless spaces, or without posterior dental support (Kennedy Classes I and II). Rehabilitation with distal extension removable partial denture (DERPD) deserves special attention because of the difference in resilience between the remaining mucosa of the edentulous area and the periodontal ligament of the abutment tooth.

When occlusal forces affect the bases, the difference in resilience between the mucosa of the edentulous area and the periodontal ligament of the abutment teeth creates a rotating movement whose axis is located on the occlusal rests on the abutment teeth. This may induce horizontal forces and mainly lateral forces upon them, causing inflammation, gingival retraction, increase in dental mobility[1,2], and distal residual ridge resorption. This movement may cause a reduction in function, discomfort and trauma to the RPD supporting tissues[3].

Several studies have therefore been performed with the aim of providing better biomechanical functioning for DERPDs, so that the stress created is distributed more favorably for the supporting structures by means of precise retainer prescription[4,5]; making a functional impression[6]; using attachments as an alternative to retainers[7,8]; splinting the distal rests for cases in which attachments are used[6]; using a large base within the physiological limitations of each patient[9]; periodic rebasing to compensate bone resorption of the residual alveolar ridge[10]; making dentures with resilient inner layers[11]; and using osseointegrated implants located in the back region of the ridge, associated or not to retention systems[12].

Studies by Kratochvil[13] and Kratochvil and Caputo[14] found that circumferential retainers produced greater tooth movement. Research by Shohet[15] confirmed that the abutment tooth bore more destructive distal forces when circumferential retainers and precision attachments were used. Thompson et al.[2] showed that the location of the occlusal rest was more relevant than retainer design, nevertheless, they also noted that in DERPD, the combination of a circumferential retainer and distal rest generated greater horizontal forces on the abutment teeth.

Miller and Grasso[16] say that several types of retainer can cause differences in the torque forces on the abutment tooth, as even placing the rests distally on the abutment tooth and using T-bar retainers, they found a reduction of forces compared to the circumferential retainer.

Kratochvil et al.[17] evaluated direct retainers with DERPD and attachment systems. Their study used the photoelastic method to compare the resultant forces on the support structures with the three most commonly used types of attachment. The results showed that all attachment types induced distal forces on abutment teeth (first premolars), causing a transmission of horizontal forces unfavorable to the alveolar bone. Nevertheless, when the first premolars were splinted to the canines, the stress was distributed, thus reducing the forces distally.

Chou, et al.[18] used photoelasticity to evaluate the characteristics of load transfer from six types of DERPD to the support tissues. Two of the designs used retention retainers (RPI and circumferential), two used semi-precision attachments (P.D. locking and Thompson Dowel non-locking) and two used precision attachments (Mc Collum and Stern G/L). Each denture was subject to several simulations of occlusal loads and photographed, and the bands were analyzed. In general, the RPDs that used attachments showed a high level of stress on the abutment tooth, compared to the ones that used retainers, and the highest were levels found for the Stern G/L precision attachment and the DERPD that used the RPI retainer, which generated the most uniform stress levels on the support structures.

Elbrecht (1937, in Rebóssio[19]) was the first to refer to the influence of sagittal inclination of the alveolar ridge in RPD cases, according to its position with relation to the occlusal plane, and classified four main ridge types: 1) horizontal ridge; 2) ridge with distal descending inclination; 3) ridge with distal ascending inclination; and 4) ridge with descending-ascending inclination. They believe that the horizontal ridge promotes a more balanced distribution of masticatory forces. On the distal-ascending ridge, the resulting force is towards the mesial part, and is annulled by the front teeth. These two ridges therefore had a good prognosis. In contrast, the distal-descending and descending- ascending ridges produce force decomposition with the resulting force putting stress on the denture towards the distal part.

The residual ridge is also responsible for supporting the DERPDs, absorbing and neutralizing vertical and horizontal or oblique loads arising from the function. Thus, the aim of this study was to use the photoelasticity method to analyze the distribution of stress formed by the incidence of loads on DERPDs (Kennedy Class I) on the abutment teeth and on residual ridges with different anatomical configurations: horizontal, distal descending, distal ascending and descending-ascending (concave), to identify the best type of retainer and best location for the rest on the mandibular abutment tooth adjacent to the distal extension.

MATERIALS AND METHODS

Four plaster casts were made from an impression of an experimental dental mannequin (Odontofix Ind. Com. Mat. Odont. Ltda.). They were prepared and the teeth that were not relevant to this study were removed, turning them into Kennedy class I by keeping only the incisors and canines in the arch. The edentulous ridge region on each model was prepared and worn down to represent different ridge shapes: horizontal (flat ridge), distal descending (sloping downward at 15º), distal ascending (sloping upward at 15º) and descending-ascending or concave (sloping down and up at 15º). When the four casts were ready, four silicone moulds were prepared for duplication (Sapeca, Bauru, São Paulo, Brazil).

Artificial teeth (canines and incisors) from the same mannequin were used to make teeth in photoelastic resin, within the standard size of natural teeth[20]. A silicone mould was made to duplicate the artificial teeth, and filled with photoelastic resin PL-1 (Vishay Measurements Group, Inc Raleigh, N.C. USA), according to the manufacturer's instructions. The photoelastic teeth were placed in the silicone moulds of the original casts, and these moulds were filled with photoelastic resin PL-2 (Vishay Measurements Group, Inc Raleigh, N.C. USA), to simulate the bone tissue. When the resin was fully polymerized, the photoelastic model was finished and polished.

Four special plaster casts (Durone, Dentsply, Rovigo, Italy) were prepared from the mould used for making the photoelastic model, in order to make the RPDs. From each plaster cast, four Cr-Co alloy metal structures were made with the different ridge shapes, providing a total sixteen RPDs, under standardized conditions and methods. All metal structures (major connector, minor connectors, rests) were checked for fit with each cast (definite and photoelastic). For all the casts, a lingual bar with the Kennedy continuous retainer (dental bar) was selected as major connector. Table 1 describes the design of each RPD.

The artificial teeth (Trilux EuroVIPI, VIPI, Pirassununga-SP, Brazil) were mounted on the distal extensions of the dentures up to the second molars. The denture base was made from heat-polymerizing acrylic resin (JET, Artigos Odontológicos Clássico Ltda., São Paulo, Brazil). To adapt the base to the model, it was lined with denture lining material (Dentusoft, Densell, Argentina). Both the resin for the base and the lining material were transparent to avoid any interference in viewing the bands. The dentures were lined a few minutes before applying the load to prevent the material from hardening.

The photoelastic model was placed in a load applying device, and the whole set completely submerged inside a glass container of mineral oil. The container was placed between a polarizing filter, an analyzing filter and two ¼ wavelength retarding filters. A light diffuser was attached beside the polarizing filter so that the white light bulb (Photoflood 500 W, General Electric Co, Cleveland, OH, USA) would shine evenly on the container with the photoelastic model. The analyzing filter was attached to a Nikon D70 digital camera (Nikon Corporation, Chiyoda-ku, Tokyo, Japan) to take the photographs. 100N axial point loads were then applied to each of the teeth in the DERPD. The images were transferred to a computer for qualitative analysis using the software Adobe Photoshop 7.0 (Adobe Systems, San Jose, California, USA).

The qualitative method is a technique that is often used for photoelastic stress analysis. The photographic records were transferred to the software Adobe Photoshop 7.0 to facilitate the analysis of the photoelastic bands (number, direction and propagation) following Caputo and Standlee[21] (Fig. 1):

- The greater the number and fringes order, the greater the magnitude of the stress.
- The closer together the bands, the greater the concentration of stress.

Table 1: RPD designs used in this study.

	Horizontal Ridge
RPD 1	Mesial rest and bar retainer
RPD 2	Distal rest and bar retainer
RPD 3	Mesial rest and circumferential retainer
RPD 4	Distal rest and circumferential retainer
	Distal Descending Ridge
RPD 5	Mesial rest and bar retainer
RPD 6	Distal rest and bar retainer
RPD 7	Mesial rest and circumferential retainer
RPD 8	Distal rest and circumferential retainer
	Distal Ascending Ridge
RPD 9	Mesial rest and bar retainer
RPD 10	Distal rest and bar retainer
RPD 11	Mesial rest and circumferential retainer
RPD 12	Distal rest and circumferential retainer
	Ascending Descending Ridge
RPD 13	Mesial rest and bar retainer
RPD 14	Distal rest and bar retainer
RPD 15	Mesial rest and circumferential retainer
RPD 16	Distal rest and circumferential retainer

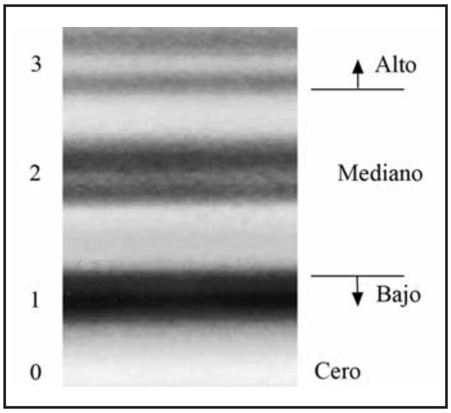

Fig. 1: Order of Bands.

RESULTS

The results (Figs. 2 to 5) were analyzed qualitatively regarding the tendency to create stress on the supporting structures (teeth and residual ridges).

According to ridge type

The horizontal ridge (Fig. 2), was the most favorable for distribution of stress on the support structures, with bands spread all over the distal ridge region, and without stress concentration. On the horizontal ridge there was no influence related to type of retainer or location of the rest, except in the association of circumferential retainer with the rest distal to the last abutment tooth (Fig. 2D).

The distal descending ridge (Fig. 3) had greatest stress concentration, and was therefore the least favorable anatomical type for support structures. Stress was produced both in the residual ridge region and around the two last abutment teeth. As ridge anatomical shape is affected by both the type of retainer and of the rest location, the association of circumferential retainer with distal rest thus had the least favorable results (Fig. 3D).

The distal ascending ridge (Fig. 4) was also quite favorable regarding stress distribution, with a small concentration of stress around the last abutment tooth adjacent to the cervical region of the tooth, to a greater or lesser extent, depending on the type of retainer and location of the rest. Stress distribution along the residual ridge was quite even, with only a small concentration of bands in the region where the ridge begins to curve upwards.

On the descending-ascending ridge (concave) (Fig. 5), band formation continued with stress concentration in the distal region of the last abutment tooth, therefore band distribution started from apical towards cervical of the abutment tooth in the direction of the descending region of the ridge, covering a greater area of residual ridge, which was more harmful to the support structures. It was also noted that there was some concentration of bands near the curve of the residual ridge, in the ascending region of the ridge, and in the distal ascending ridge (Fig. 4).

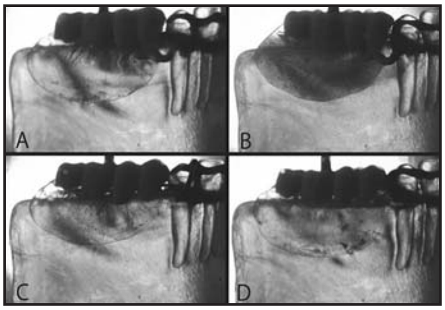

Fig. 2: HORIZONTAL RIDGE: a) Bar retainer and mesial rest; b) Bar retainer and distal rest; c) Circumferential retainer and mesial rest; d) Circumferential retainer and distal rest.

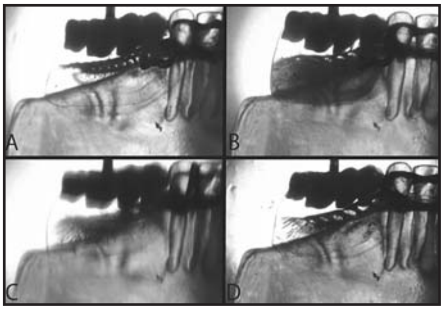

Fig. 3: DISTAL DESCENDING RIDGE. a) Bar retainer and mesial rest; b) Bar retainer and distal rest; c) Circumferential retainer and mesial rest; d) Circumferential retainer and distal rest.

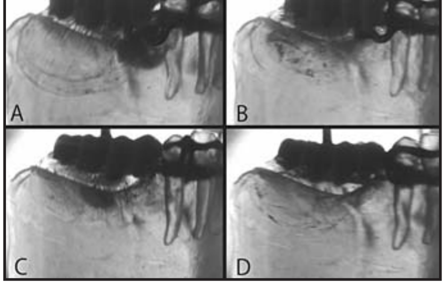

Fig. 4: DISTAL ASCENDING RIDGE. a) Bar retainer and mesial rest; b) Bar retainer and distal rest; c) Circumferential retainer and mesial rest; d) Circumferential retainer and distal rest.

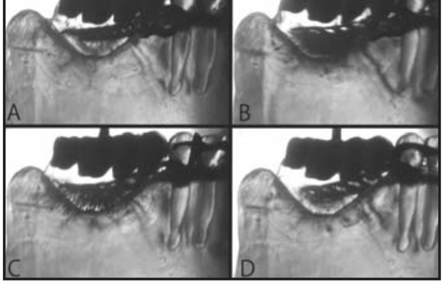

Fig. 5: ASCENDING DESCENDING RIDGE. a) Bar retainer and mesial rest; b) Bar retainer and distal rest; c) Circumferential retainer and mesial rest; d) Circumferential retainer and distal rest.

According retainer type

With regard to the type of retainer used, we found that the circumferential retainer produced more photoelastic bands than the T bar retainer, regardless of the location of the rest and the type of ridge analyzed, when comparing this variable only and maintaining the rest position and type of residual ridge, with the exception of the horizontal ridge (Fig. 2), on which retainer type did not have a great influence on stress distribution.

According to rest location

Regarding the location of the rest on the last abutment tooth, we found similar results when it was positioned on the mesial or distal part of the tooth; regarding formation and magnitude of the stress generated, regardless of the shape of the ridge analyzed, except for the distal descending ridge (Fig. 3), where there was an increase in the magnitude of the photoelastic bands when the rest was located distally on the last abutment tooth.

DISCUSSION

There are few studies discussing the shape of the residual ridge types and their influence on the other DERPD supporting structures. The residual ridge is one of the structures directly linked to dissipating forces that affect the denture, and to its stability. According to the results of this study, the horizontal ridge and the distal ascending ridge were the types of ridge that were most favorable in stress distribution, in agreement with other studies[22-25]. Nevertheless, Plaza[22] only analyzed horizontal and descending-ascending ridge shapes using the finite element methodology and concluded that the horizontal shape was more favorable to support structures and had better stress distribution.

Similarly, our study agrees with research by Martin Júnior[26], who found that for most of the aspects analyzed, the distal descending ridge was the shape that had the greatest concentrations of stress.

The type of retainer to be used in removable partial dentures is extremely important because it is responsible for retaining the RPD, and the choice is even more relevant when it is a DERPD, and the transmission of forces to the last abutment teeth comes from the arm of the retainer. In our study, the circumferential retainer was the type that transmitted greatest concentrations of stress to the support structures of the DERPD of the photoelastic models, in agreement with other studies[2,5,18], though contrasting with results obtained in studies in which the circumferential retainer was more effective at the distal extension[27], however, in this study, the circumferential retainer had another rest located on the tooth mesial to the last abutment tooth, and the distal extension studied was small, which might explain the result obtained by the author.

With regard to the mesial or distal location of the rest on the last abutment tooth, it may be said that both showed similar behavior, making it impossible to decide upon the best position for the rest, in agreement with the result of another study which, similarly, found no statistically significant difference on comparing dentures using circumferential and RPI retainers, with rests located distally or mesially to the abutment tooth[7]. However, other studies[2,13,27] have shown that when the occlusal rest was located on the mesial region of the last abutment tooth, the perpendicular forces on the mucosa of the residual ridge were more beneficial to it, while if the occlusal rest was located on the distal region of the last abutment tooth, the structures received more stress. There are still authors who support locating the rest distally, not only considering the biomechanical aspect, which consists of increasing the resistance arm of the DERPD, but also considering the periodontal standpoint, in connection to being able to reduce the possibility of forming gingival hyperplasia between the rest and the base of the denture, even though they believe that the mesial location of the rest enables occlusal forces to be transmitted more vertically, and therefore in a more beneficial way for the support structures[28].

CONCLUSION

Within the limitations of the methodology used and from the results obtained, it may be concluded that:

1. The situation of the distal descending ridge was the least favorable and that of the horizontal ridge was the most favorable.
2. The T-bar retainer had the most favorable stress distribution, except in the case of the horizontal ridge, where there was no influence with relation to retainer type.
3. The location of the rest showed similar behavior except on the distal descending ridge.

CORRESPONDENCE
Eduardo Piza Pellizzer
Rua José Bonifácio, 1193 - Vila Mendonça
CEP 16015-050, Araçatuba-São Paulo, Brazil
e-mail: ed.pl@uol.com.br

REFERENCES

1. McCracken's removable partial prosthodontics, Carr AB, McGivney GP, Brown DT. 11h ed., Mosby Inc, 2004.
2. Thompson WD, Kratochvil FJ, Caputo AA. Evaluation of photoelastic stress patterns produced by various designs of bilateral distal-extension removable partial dentures. J Prosthet Dent 2004;91:105-113.
3. Igarashi Y, Ogata A, Kuroiwa A, Wang CH. Stress distribution and abutment tooth mobility of distal-extension removable partial dentures with different retainers: an in vivo study. J Oral Rehabil 1999;26:111-116.
4. Tebrock OC, Rohen RM, Fenster RK, Pelleu GB Jr. The effect of various clasping systems on the mobility of abutment teeth for distal-extension removable partial dentures. J Prosthet Dent 1979;41:511-516.
5. Morikawa M, Masumi S, Kido H, Kosono Y. Analysis of abutment tooth movement utilizing mandibular kinesiograph (MKG). Dent Mater J 1989;8:56-64.
6. El Charkawi HG, El Wakad MT. Effect of splinting on load distribution on extracoronal attachment with distal extension prosthesis in vitro. J Prosthet Dent 1996;76:315-320.
7. Chou TM, Eick JD, Moore DJ, Tira DE. Stereophotogrammetric analysis of a abutment tooth movement in distal-extension removable partial dentures with intracoronal attachments and clasps. J Prosthet Dent 1991;66:343-349.
8. Ku YC, Shen YF, Chan CP. Extracoronal resilient attachments in distal-extension removable partial dentures. Quintessence Int 2000;31:311-317.
9. Mutarelli PS. Discussão e avaliação do planejamento da prótese parcial removível de extremidade livre. 115f. Dissertação (Mestrado) - Faculdade de Odontologia da Universidade de São Paulo, São Paulo, 1994.
10. Preiskel HW. Impression techniques for attachment-retained distal extension removable partial dentures. J Prosthet Dent 1971;25:620-628.
11. El Charkawi HG, Goodking RJ, Delong R, Douglas WH. The effect of the resilient-layer distal-extension partial denture on movement of the abutment teeth: a new methodology. J Prosthet Dent 1988;60:622-630.
12. Verri FR, Pellizzer EP, Rocha EP, Pereira JA. Influence of Length and Diameter of Implants Associated With Distal Extension Removable Partial Dentures. Implant Dent 2007; 16:270-280.
13. Kratochvil FJ. Influence of occlusal rest position a clasp design on movement of abutment teeth. J Prosthet Dent 1963;13:114-124.
14. Kratochvil FJ, Caputo AA. Photoelastic analysis of pressure on teeth and bone supporting removable partial dentures. J Prosthet Dent 1974;32:52-61.
15. Shohet H. Relative Magnitudes of stress on abutment teeth with different retainers. J Prosthet Dent 1969;21:267-282.
16. Removable Partial Prosthodontics. Miller EL, Grasso J.E, 3rd edition, Mosby, 1991.
17. Kratochvil FJ, Thompson WD, Caputo AA. Photoelastic analysis of stress patterns on teeth and bone with attachment retainers for removable partial dentures. J Prosthet Dent 1981;46:21-28
18. Chou TM, Caputo AA, Moore DJ, Xiao B. Photoelastic analysis and comparison of force transmission characteristics of intracoronal attachments with clasp distal-extension removable partial dentures. J Prosthet Dent 1989;62:313-319
19. Prótesis parcial removible. Rebossio AD. 3rd ed. Ed. Mundi, 1963.
20. Oral anatomy, embryology and histology. Berkovitz BKB, holland GR, Moxham BJ. 3rd ed. Mosby, 2002.
21. Biomechanics in Clinical Dentistry. Caputo AA, Standlee JP. Quintessence Publishing Co., 1987.
22. Plaza CAS. Análise comparativa, pelo método dos elementos finitos bidimensional, das tensões parcial removível de extremidade livre inferior, em rebordo horizontal e descendente-ascendente. 170f. Dissertação (Mestrado) – Faculdade de Odontologia, Universidade de São Paulo, São Paulo, 2004.
23. Camargo RZB. Análise comparativa pelo método dos elementos finitos bidimensional das tensões geradas nas estruturas de suporte de prótese parcial removível de extremidade livre inferior sobre rebordo residual ascendente distal e descendente distal. 193f. Dissertação (Mestrado) - Faculdade de Odontologia, Universidade de São Paulo, São Paulo, 2005.
24. Lucas LVM. Influência do formato do rebordo na associação de uma prótese parcial removível de extremidade livre mandibular associada ao implante com sistema ERA de retenção, pelo método dos elementos finitos. 154f. Tese (Doutorado) - Faculdade de Odontologia, Universidade Estadual Paulista, Araçatuba, 2006.
25. Cunha LDP, Pellizzer EP, Verri FR, Pereira JA. Evaluation of the Influence of Location of Osseointegrated Implants Associated with Mandibular Removable Partial Dentures. Implant Dent 2008;16:278-287.
26. Martin Júnior M. Influência do formato do rebordo alveolar na distribuição interna das tensões em prótese parcial dentoimplantossuportada. 196f. Dissertação (Mestrado) - Faculdade de Odontologia de Araçatuba, Universidade Estadual Paulista, Araçatuba, 2005.
27. Nally JN. Methods of handling abutment teeth in Class I partial dentures. J Prosthet Dent 1973;30:561-566.
28. Sousa V, Pellizzer EP, Garcia AR, Zuim PRJ. Apoio oclusal em casos de extremidade livre. Rev Odontol UNESP 1992; 31:351-357.