EVALUATION OF THE OCCLUSAL CONTACT AREA OF MOLAR DENTAL IMPLANTS COMPARING TWO DIFFERENT THICKNESSES (16 µm AND 200 µm) OF ARTICULATING OCCLUSAL PAPERS AND FORCES (200 AND 250 N): A PIVOT IN VITRO STUDY

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ABSTRACT

Introduction: The goal of this pilot study was to evaluate the differences between checking occlusion on implants crowns using 16 or 200 µm thickness of articulating occlusal paper, and to compare the stained occlusal area between the groups after bite forces of 200 and 250 N. **Methods:** It was included 10 casts of articulated-type IV gypsum, 10 NiCr crowns, articulating occlusal papers (16 µm and 200 µm thick), and a compression test machine. Compressive forces (200 and 250 N.mm) were applied on models, to check the occlusal contact area of fixed and cemented crowns. The contact areas on the crowns were measured through images obtained by the scanning electron microscope. Statistical tests were performed considering the significant level of 5% ($p \leq 0.05$). **Results:** The stains found using 200 µm of articulating paper were higher than those with 16 µm, independent of the force applied. However, the stains obtained in lower teeth with different strengths (200 and 250N) marked with 16 µm articulating paper were not possible to score. The articulating paper variable had significant statistical results ($p=0.002$), while the variables force ($p=0.443$) and articulating paper-force interaction ($p=0.607$) were not significant. The mean area found in staining using the 200 µm and 16 µm papers was, respectively, 8.3380 mm2 and 3.4759 mm2. **Conclusion:** It was possible to confirm that 200 µm of articulating occlusal paper showed better and significant results to stain the occlusal area, permitting a more accurate adjustment independent of the force applied.

Keywords: Occlusion, Dental implant, Compressive forces, Occlusal paper, Contact area.

INTRODUCTION

Oral rehabilitation using dental implants has had a highly increased demand. Therefore, it is crucial to highlight biophysiological differences when comparing natural teeth and dental implants. Whereas in the natural tooth, the periodontal mechanoreceptors promote tactile sensitivity (proprioception) through the periodontal ligaments, in dental implants, there is the osseoperception[1] effect due to the osseointegration process, providing a considerably lower tactile sensitivity.

Thus, the periodontal ligaments allow the perception of an axial and lateral displacement in a functional load of, respectively, 25-100 μm and 56-108 μm. On the other hand, the micromovement on the dental implants is minimum, varying around 3-5 μm axially and 10-50 μm laterally.[2-4] Therefore, the principles of occlusion employed on dental implants are based on the same methods applied for natural teeth. Nevertheless, while the minimum ability of perception in the occlusion of natural teeth is approximately 20 μm and dentures are around 40 μm, dental implants are about 64 micrometers.[4-7]

There is a response to increased mechanical stress until a certain threshold, strengthening the bone by apposition or increasing the bone density[8,9]. Otherwise, fatigue microdamage may result in bone resorption as a product of mechanical stress above this threshold[10]. Then, in mild or moderate-contact intensities in the maximum intercuspation position, there should be a relief of approximately 30 μm between the occlusal faces of the prosthesis and the opposite arch. This relief or infraocclusion compensates for the biomechanical differences between teeth and implants, avoiding an overload for implants. As the most intense natural force, the bite force applied to the teeth and implants occurs during chewing.[11]

The clinical success rate and the longevity of the restorative treatments using fixed prostheses on dental implants are directly related to biomechanical occlusion control. Due to the absence of periodontal ligaments in implants, the reaction to occlusal forces is considered biomechanically different, unlike natural teeth.[11] That fact may cause implant failures, specifically attributing to an inadequate occlusal scheme, which concentrates undesirable stresses on the peri-implant bone tissue. Furthermore, occlusal overloading is considered one of the leading causes of marginal bone loss (MBL) and implant failures. Also, it might cause loosening of the intermediate screw, loss of retention or cementation, fracture of the prosthetic component or implant, fracture of restorative materials, and loss of osseointegration.[4]

Considering the importance of a balanced occlusion in treatments with dental implants, looking to keep a mutual protected or cuspid guided occlusion, the goal of this *in vitro* pilot study was primarily to evaluate the differences between check occlusion on implants crowns using 16 or 200 μm thickness of articulating occlusal paper; and, secondarily, to compare the stained occlusal area between the groups after bite forces of 200 and 250 N. The findings of this study can improve the clinical understanding of selecting different types of occlusal papers and show the differences when the patient has an augmented bite force.

The positive hypothesis was that the 200 μm thickness of articulating occlusal paper might better detect the occlusal stains for both forces implemented.

METHODS

For this pilot study, it was included ten casts (five models) of articulated-type IV gypsum, prepared by the same professional, to evaluate the occlusion of 10 antagonist and polished NiCr crowns (over dental implants) (Fig. 1); articulating occlusal papers with 16 μm (Gnatho-Film Soft Occlusal Film - 16 Microns, BK 120, Bausch Articulating Papers, Inc.) and 200 μm thick (Bausch 200 Micron Articulating Paper 300/Box, Bausch Articulating Papers, Inc.); EMIC DL 10,000 compression test machine; and software for test automation TESC EMIC (v. 3.04 with TRD cell 21 - 500 N) (Fig. 2).

Fig. 1. Articulated plaster model with NiCr crowns.

Fig. 2. EMIC testing machine (compressive forces applied).

The study consisted of compressive forces applied on models of NiCr crowns fitted on dental implants at the first molar sites. The method evaluated different forces intensity (200 and 250 N.mm) used on gypsum models to check the occlusal contact area of fixed and cemented crowns. The models were developed to obtain stains on the occlusion area representing the contact marked with articulating papers of 16 and 200 µm of thickness. Afterward, the contact areas on the crowns were measured by the same professional through images obtained by the scanning electron microscope (JSM-5800 SEM, ACCV 20kV).

It was used the following formula (tension=force/area) to evaluate the suggestive stresses transmitted to the implant-bone complex. Then, the forces and areas were obtained through the tests performed to reach the possible tension.

Statistical tests were performed considering the significant level of 5% ($p \leq 0.05$). Firstly, the Levene test was applied to verify the homogeneity of the data, and after, it was used ANOVA. Moreover, the contingency table and Box Plot graph were a descriptive analysis of the data. The contingency table was initially performed to do a descriptive analysis of the stain according to the articulating paper used. The forces were applied to verify which variable was more significant concerning the articulating paper type and the average area found in the stain.

RESULTS

The results for contingencies are in Table 1. The stains found using 200 µm of articulating paper (Fig. 3) were higher than those with 16 µm of articulating paper, independent of the force applied. However, the stains obtained in lower teeth with different strengths (200 and 250N.mm) marked with 16 µm articulating paper were not possible to score, excluding five lower casts data from the analysis.

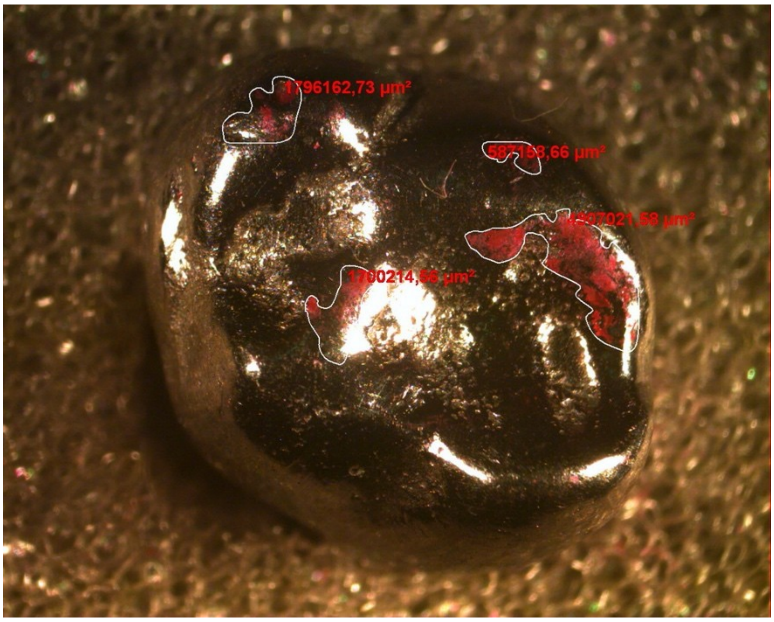

Fig. 3. Carbon marking after occlusion be checked in scanning electron microscope.

Table 1. Analysis of the stain according to the articulating paper used and forces applied.

	Force (N.mm)	Mean area (mm^2)	Standard Deviation (± SD) (mm^2)	IC 95%	*n*
200 µm thickness	250	8.5223	3.75962	6.192 - 10.853	10
	200	8.1537	4.50947	5.359 - 10.949	10
	Total	**8.3380**	**4.04521**	**6.565 - 10.111**	**20**
16 µm thickness	250	4.4061	2.98934	1.786 - 7.026	5
	200	2.5458	1.48271	1.246 - 3.845	5
	Total	**3.4759**	**2.43106**	**1.969 - 4.983**	**10**
TOTAL	250	7.1502	3.95904	5.147 - 9.154	15
	200	6.2844	4.60313	3.955 - 8.614	15
	Total	**6.7173**	**4.24142**	**5.199 - 8.235**	**30**

After confirming the homogeneity of the data (p=0.151), an ANOVA test was carried out for the variables (i) articulating paper, (ii) forces, (iii) articulating paper-force interaction, and (iv) stains (Table 2). The articulating paper variable had significant statistical results (p=0.002), while the variables force (p=0.443) and articulating paper-force interaction (p=0.607) were not significant (Fig. 4). Thus, the interpretation is the difference between stains is mainly due to the articulating paper used, i.e., the use of the same articulating paper under different forces did not cause significant differences in the stain. The 200 μm presented a higher score than the 16 μm articulating paper under any condition (Fig. 5). The superior difference of mean area found in staining using the 200 μm occlusal papers in contrast to the 16 μm was 4.8621 mm^2, respectively, 8.3380 mm^2 for 200 μm and 3.4759 mm^2 for 16 μm.

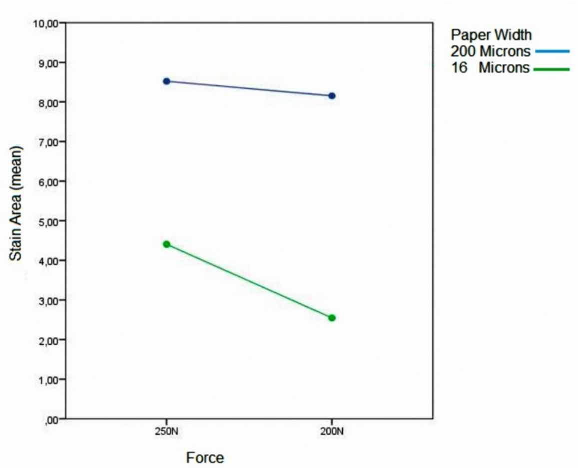

Fig. 4. The absence of the interaction effect is illustrated by the more pronounced parallelism than the tendency to cross the lines.

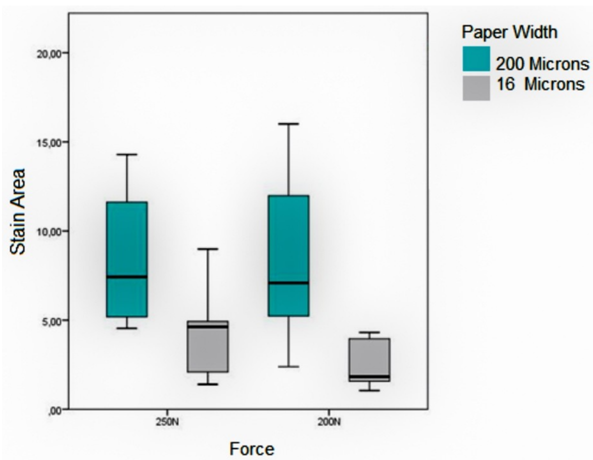

Fig. 5. Illustrates how the stain is an effect of the articulating paper effect. The same articulating paper under different forces implies similar stain results. However, different articulating papers under the same force or different forces implied in different stain results.

To evaluate the suggestive stresses transmitted to the implant and bone, Table 2 summarizes the forces performed in the tests and the means of the areas found. Then, the average area obtained after using 200 µm of articulating paper was 8.33 mm^2, suggesting that this occlusal paper may cause lower stress to the implant-bone complex (29.5 $N.mm^{-2}$) when used a force of 250 N of compression, whereas 24.7 $N.mm^{-2}$ was found using 200 N.

Table 2. Suggestive transmitted tension according to the articulating paper thickness.

Tension with 250 N of compressive force		
200 µm thickness	T = (F / S) = 250 N / 8.5 mm^2	T = 29.5 $N.mm^{-2}$
16 µm thickness	T = (F / S) = 250 N / 4.4 mm^2	T = 56.8 $N.mm^{-2}$
Tension with 200 N of compressive force		
200 µm thickness	T = (F / S) = 200 N / 8.1 mm^2	T = 24.7 $N.mm^{-2}$
16 µm thickness	T = (F / S) = 200 N / 2.5 mm^2	T = 80.0 $N.mm^{-2}$

F = force; N = Newtons; S = area.

For 16 µm of articulating paper, it presented a mean area of 3.47 mm^2, in which tension of 80 $N.mm^{-2}$ was obtained after using a compression force of 200 N and 56.8 $N.mm^{-2}$ when using the force of 250 N, observing that few teeth showed stain when submitted to the tests with articulating paper of 16 µm. It is suggested that 16 µm articulating paper did not permit a correct analysis of the occlusion, consequently impairing the verification of the suggestive stresses load transmitted to the bone-implant complex.

All occlusal areas evaluated and found in the NiCr crowns using 16 µm and 200 µm articulating occlusal papers, with compressive forces of 200 and 250 N, are shown in Table 3.

Table 3. Stains measurements of the areas of occlusal contact.

	A	B	C	D	E	F
	Maxilla 200 µm 250 N.mm	**Mandible 200 µm 250 N.mm**	**Maxilla 16 µm 250 N.mm**	**Maxilla 200 µm 200 N.mm**	**Mandible 200 µm 200 N.mm**	**Maxilla 16 µm 200 N.mm**
Model 1	10.1 mm^2	14.06 mm^2	4.9 mm^2	12.0 mm^2	16.0 mm^2	4.3 mm^2
Model 2	5.91 mm^2	7.16 mm^2	4.6 mm^2	6.3 mm^2	4.0 mm^2	1.1 mm^2
Model 3	5.18 mm^2	7.68 mm^2	2.1 mm^2	5.2 mm^2	2.4 mm^2	1.8 mm^2
Model 4	11.62 mm^2	4.68 mm^2	9.0 mm^2	5.5 mm^2	7.9 mm^2	1.6 mm^2
Model 5	14.29 mm^2	4.54 mm^2	1.4 mm^2	14.2 mm^2	8.1 mm^2	4.0 mm^2
Average (± SD)	**9.42 (3.85) mm^2**	**7.624 (3.87) mm^2**	**4.406 (2.99) mm^2**	**8.644 (4.17) mm^2**	**7.664 (5.26) mm^2**	**2.546 (1.48) mm^2**

DISCUSSION

Occlusal load

The goal of the occlusion adjustment in dental implants is to minimize overloads on the bone-implant interface. Implant failures may be related to occlusal overload and poor bone strength around the implant. Unlike the tooth, the osseointegrated implants have an absence of periodontal ligament, which limits the perception and renders the damping system of dental implants very deficient.[12] An inadequate occlusal scheme may concentrate tensions on the peri-implant bone tissue favoring the chance of failures, such as loosening of the intermediate, loss of retention, abutment screw fracture, restorative materials fracture, failure of the cementation interface, implant fracture, and loss of osseointegration[13-18].

The dental implants are subjected daily to occlusal loads, which can vary drastically in magnitude, frequency, and duration, depending on the functional or parafunctional habits of the patient. Masticatory forces differ significantly during the chewing stages, and several authors have evaluated their magnitude. Studies developed between 1977 and 2008 evaluated different occlusion forces, and they found values between 60 and 220 N.[19-22] Other authors evaluated occlusal overload using interceptive premature contacts on implants placed in monkeys and concluded there was a significant statistical difference between groups with implants without occlusal contact or with occlusal contact up to 100 μm *versus* with occlusal interference of 180-250 μm.[23] The findings after comparing 100, 180, and 250 μm of interocclusal staining showed that the crestal bone levels for 100 μm and dental implants without occlusal contact were similar. However, there was a significant difference in the bone loss for groups with contacts of 180 and 250 μm. This fact trigged the use of articulating occlusal papers in the present study.

Thus, the present pilot study performed biomechanical tests and compressive assays with 200 N and 250 N forces to analyze the occlusal surface contact area, following previous publications to standardize the maximum bite force.[19,21,23,24] To find the stains on the crowns, two articulating papers were tested (16 μm and 200 μm of thickness)[22,25,26] on molars sites. This research presented 8.33 mm^2 and 3.47 mm^2 for areas using articulating papers of, respectively, 200 μm and 16 μm of thick, comparing the two applied forces (200 N and 250 N).

Occlusal contact area

In 2000, a study[25] aimed to evaluate the contact area of the anterior and posterior teeth separately for the level of tightness, using a silicone of 50 μm of thickness. The hypothesis was the area of occlusal contact increases simply with the rise in levels of tightening, independent of the region in the dental arch. The authors concluded that the occlusal contact areas of the premolars and molars increased according to force increase. In contrast, the anterior teeth had not changed, rejecting the proposed hypothesis.

Also, according to another study,[26] when the bite force is increased, the occlusal contact area is increased, which is more evident in posterior than the anterior teeth. The authors used a pre-scale dental measurement system to evaluate the bite forces and the occlusal contact area in each tooth in the intercuspation position using a stained sheet with 97 μm and wax with 800 μm of thickness. The first was used for accurate bite force measurement, occlusal contact area, and mean pressure, and the second marker was used to detect the contour of the teeth and the location of the occlusal contacts. The authors employed a force of 520 N expressing 14 mm^2 of occlusal contact area; with 806 N expressing an occlusal contact area of 21.3 mm^2; and at maximum voluntary strength (1181 N) expressing 30.2 mm^2 of the occlusal contact area.

Two studies[26,27] carried out tests with the pre-scaling dental system, applying 20%, 40%, 60%, 80%, and 100% tightening. The authors divided the analyzes into five regions (right and left molar, right and left premolar, and anterior teeth). They introduced three parameters for evaluation: occlusal force, occlusal contact area, and occlusal force ratio. The authors concluded the contact areas increased according to the bite forces rose, higher in the molar region, with forces presented at 365.2 N in the right molars and a contact area of 10 mm^2 and the left molar force 353.4 N with an area of 9.5 mm^2.

This study agrees with previous studies,[25-28] which concluded that the occlusal contact area increases the occlusal strength. Moreover, posterior teeth have more occlusal contacts than anterior teeth, and contact areas were more present during masticatory movements.

Suggestive stress transmitted to bone-implant complex

In oral rehabilitation, the biomechanics involving dental implants and final prostheses should be balanced concerning the occlusion, which can be considered a risk factor for bone loss and implant loss.[29] Once peri-implantitis is established, the overload occlusion and inflammation remotion may not be enough to promote the cure mechanism.[30]

In the current study, suggestive bone-implant stress transmission of 29.5 N/mm^2 and 56.8 N/mm^2 was found in the application of 250 N of compressive strength with articulating papers of, respectively, 200 μm and 16 μm; and a suggestive tension of 24.7 N/mm^2 and 80 N/mm^2 associated with compressive forces of 200 N with articulating paper of, respectively, 200 μm and 16 μm of articulating papers. According to studies published,[23,31,32] the bone should receive a maximum tension ranging between 100 and 167 N. These values would be the threshold to boost bone resorption. In contrast, the limits of the compression forces range from 36 to 375 N and tensile strength from 18 to 100 N in both maxilla and mandible. Another study has shown that for healthy peri-implant mucosa, occlusal overload increased bone-to-implant contact and caused mild marginal bone loss. However, overloading worsened MBL in cases with inflammation.[33]

Limitation of the study

This study was a pilot *in vitro* study, which included a reduced number of samples to primarily find possible differences to check occlusion using different occlusal papers (16 μm and 200 μm thickness) and, secondarily, to verify the influence of compressive forces on the stain of the contact areas. The results showed statistical differences using different thicknesses of paper, which stimulated other *in vitro* and *in vivo* studies, including more samples or patients. Moreover, even though SEM was used to analyze, it could currently be suggested to explore digital tools.

CONCLUSIONS

Within the limitations of this study, it was possible to confirm the positive hypothesis that 200 μm of articulating occlusal paper showed better results to stain the occlusal area, permitting a more accurate adjustment independent of the force applied. Moreover, there was a significant difference between stains using 200 μm and 16 μm of occlusal paper. Consequently, this fact suggests that a lower probability of undesired forces being transmitted to the dental implants and 16 μm occlusal paper did not permit a correct occlusal analysis. Thus, more studies are suggested, such as adding other materials (ceramics and composites) and tests with different articulating paper thicknesses, to confirm the findings of this pilot study.

REFERENCES

1. Dhall, R.S., Gupta, G., Ahluwalia, S., Rawat, A., and Gaur, A. Osseoperception in dental implants. IP. Int. J. Periodont. Imp., 2017; **2**:130-135.

2. Kim, Y., Oh, T.J., Misch, C.E., and Wang, H.L. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. Clin. Oral Implants Res., 2005; **16**:26-35.

3. Gross, M.D. Occlusion in implant dentistry: a review of the literature of prosthetic determinants and current concepts. Aust. Dent. J., 2008; **53**:60-68.

4. Rilo, B., Silva, J.L., Mora, M.J., and Santana, U. Guidelines for occlusion strategy in implant-borne prostheses: a review. Int. Dent. J., 2008; **58**:139-145.

5. Misch, C.E. Implantes dentais contemporâneos. 4th ed. Rio de Janeiro: Elsevier Editora Ltda, 2009; 105-106.

6. Misch CE. Implantes dentais contemporâneos. 4th Rio de Janeiro: Elsevier Editora Ltda, 2009; 557-558.

7. Klineberg, I.J., Trulsson, M., and Murray, G.M. Occlusion on implants – is there a problem? J. Oral Rehab., 2012; **39**:522-537.

8. Frost, H.M. A 2003 update of bone physiology and Wolff's law for clinicians. Angle Orthod., 2004; **74**:3-15.

9. Frost, H.M. Wolff's law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod., 1994; **64**:175-188.

10. Isidor, F. Influence of forces on peri-implant bone. Clin. Oral Implants Res., 2006; **17**:8-18.

11. Sanitá, P.V., Pinelli, L.A.P., Silva, R.H.B.T., and Segala, J.C.M. Aplicação clínica dos conceitos oclusais na Implantodontia. RFO, 2009; **14**:268-275.

12. Misch, C.E., Suzuki, J.B., Misch-Dietsh, F.M., and Bidez, M.W. A positive correlation between occlusal trauma and peri-implant bone loss: literature support. Imp. Dent., 2005; **14**:108-116.

13. Nikolopoulou, F. and Ktena-Agapitou, P. Rationale for choices of occlusal schemes for complete dentures supported by implants. J. Oral Implant., 2006; **32**:200-203.

14. Carlsson, G.E. Dental occlusion: modern concepts and their application in implant prosthodontics. Odontology, 2009; **97**:8-17.

15. Cerbasi, K.P. Etiologia bacteriana e tratamento da peri-implantite. Innov. Imp. J., Biomater. Esthet., 2010; **1**:50-55.

16. Dalago, H.R., Souza, J.C.O., Filho, G.S., Vasconcellos, D.K., and Cardoso, A.C. Relação de falhas funcionais de próteses sobreimplantes com parâmetros clínicos. ImplantNews, 2011; **8**:855-858.

17. Furrer, S.K., Colombini-Ishikiriama, B.L., Oliveira, T.M., Almeida, A.L.P.F., Monteiro-Amado, F., Santos, C.F., and Figueiredo, C.M. Peri-implantite: alternativas de tratamento. ImplantNews, 2011; **8**:297-304.

18. Zanivan, D.S., Elias, C.N., and Daróz, S.R. Análise da superfície de fratura de Implante osseointegrado e mecanismos envolvidos na cicatrização. ImplantNews, 2009; **6**:39-46.

19. Haraldson, T. and Carlsson, G.E. Bite force and oral function in patients with osseointegrated oral implants. Scand. J. Dent. Res., 1977; **85**:200-208.

20. Richter, E.J. In vivo vertical forces on implants. Int. J. Oral Maxillofac. Implants, 1995; **10**:99-107.

21. Morneburg, T.R. and Proschel, P.A. Measurement of masticatory forces and implant loads: a methodologic clinical study. Int. J. Prosthod., 2012; **15**:20-27.

22. Miyata, T., Kobayashi, Y., Araki, H., Motomura, Y., and Shin, K. The influence of controlled occlusal overload on peri-implant tissue: a histologic study in monkeys. Int. J. Oral Maxillofac. Implants, 1998; **13**:667-683.

23. Baggi, L., Cappelloni, I., Di Girolamo, M., and Maceri, F. The influence of implant diameter and length on stress distribution of osseointegrated implants related to crestal bone geometry: A three-dimensional finite element analysis. J. Prosthet. Dent., 2008; **100**:422-431.

24. Braun, S., Bantleon, H.P., Hnat, W.P., Marcotte, M.R., and Johnson, B.E. A study of bite force. Part 1: Relationship to various physical characteristics. Angle Orthod., 1995; **65**:367-372.

25. Gurdsapsri, W., Ai, M., Baba, K., and Fueki, K. Influence of clenching level on intercuspal contact area in various regions of the dental arch. J. Oral Rehabilit., 2000; **27**:239-244.

26. Hidaka, O., Iwasaki, M., Saito, M., and Morimoto, T. Influence of clenching intensity on bite force balance. occlusal contact area and average bite pressure. J. Dent. Res., 1999; **7**:1336-1344.

27. Kumagai, H., Suzuki, T., Hamada, T., Sondang, P., Fujitani, M., and Nikawa, H. Occlusal force distribution on the dental arch during various levels of clenching. J. Oral Rehabilit., 1999; **26**:932-935.

28. Riise, C. and Ericsson, S.G. A Clinical study of the distribution of occlusal tooth contacts in the intercuspal position at light and hard pressure in adults. J. Oral Rehabilit., 1983; **10**:473-480.

29. Miyata, T., Kobayashi, Y., Araki, H., Ohto, T., and Shin, K. The Influence of controlled occlusal overload on peri-implant tissue. Part 4: a histologic study in monkeys. Int. J. Oral Maxillofac. Implants 2002; **17**:384-390.

30. Kozlovsky, A., Tal, H., Laufer, B.Z., Leshem, R., Rohrer, M.D., and Weinreb, M. Impact of implant overloading on the peri-implant bone in inflamed and non-inflamed peri-implant mucosa. Clin. Oral Implants Res., 2007; **18**:601-610.

31. Çiftçi, Y. and Canay, S. The effect of veneering materials on stress distribution in implant supported fixed restorations. Int. J. Oral Maxillofac. Implants, 2000; **15**:571-582.

32. Natali, A.N., Hart, R.T., Pavan, P.G., and Knets, I. Mechanics of bone tissue. In: Natali AN. editor. Dental Biomechanics. London: Taylor & Francis, 2003; 1-19.

33. Machado, M.A.S., Júnior, A.F., Júnior, A.C., and Lustosa, A.B. Causas da perda de crista óssea peri-implantar durante o primeiro ano em função. ImplantNews, 2007; **6**:673.