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BIOMECHANICAL ANALYSIS OF THE STRESSES GENERATED BY DIFFERENT DISOCCLUSION PATTERNS IN AN IMPLANT-SUPPORTED MANDIBULAR COMPLETE DENTURE

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ABSTRACT

Objectives: This study evaluated by three-dimensional finite element analysis the tensions generated by different disocclusion patterns (canine guide and bilateral balanced occlusion) in an implant-supported mandibular complete denture. Material and Methods: A three-dimensional model of implant-supported mandibular complete denture was fabricated according to the Brånemark protocol. A 5-element 3.75 x 13-mm screw-shape dental implant system was modeled for this study. The implants were located in the inter-mental foramen region with 3-mm-high prosthetic components joined by a nickel-chromium framework with 12-mm bilateral cantilever covered by acrylic resin and 12 acrylic denture teeth. SolidWorks® software was used before and after processing the simulations. The mechanical properties of the components were inserted in the model and a 15 N load was established in fixed points, in each one of the simulations. Data were collected in the entire nickel-chromium framework. The results were displayed three-dimensionally as color graphic scales. Results: The canine guide generated greater tensions in the region of the first implant, while the bilateral balanced occlusion generated great tensions in the entire metallic framework. The maximum tension found in the simulation of the bilateral balanced occlusion was 3.22 fold higher than the one found in the simulation of the disocclusion in canine guide. Conclusion: The pattern of disocclusion in canine guide is the ideal for implant-supported mandibular complete denture.

Key words: Dental implants. Occlusion. Biomechanics.

INTRODUCTION

A great controversy is noticed in literature on how disocclusion patterns must be established in implant-supported rehabilitations[5,8,14]. Since the introduction of the osseointegration concept and the Brånemark protocol according to which a fixed denture with 5 or 6 implants as pillars is placed in the mental region with bilateral cantilevers, there has been not only an interest in demonstrating and identifying more adequate occlusion factors, providing a more harmonious and efficient disocclusion, but also in understanding their relations with the stomatognathic system[11]. The association of these factors has been investigated to determine the relationship between these factors and the masticatory muscles, chewing efficiency, bruxism, temporomandibular joint and adjacent tissues and structures. However, few consistent and research-based conclusions have been reached.

Canine guides have been used more frequently in contact movements in natural dentition[22]. The oclusal pattern can be considered a critical factor for the longevity of the osseointegrated implants, since in natural dentition, the periodontal ligament behave differently from which occurs with osseointegrated implant pillars. In this way, the tensions transmitted to the implant components and the bone/implant interface are completely different from those that are verified in the natural dentition. If the occlusion forces exceed the capacity of absorption of the system, the implant will fail due to the overloads and inadequate distribution of the masticators forces, among other factors[5,14].

The literature is poor in qualitative and quantitative evaluations of the effect of tensions generated on dentures and consequently on the prosthetic components, implants and bone structures that are supporting them. Modeling of these tensions using graphics software for biomechanical analysis by three-dimensional (3D) finite element analysis (FEA) is a promising alternative for this type of evaluation with the additional advantage of not being invasive and contributing for studies on hard-to-reach regions or impracticable conditions, such as measuring tensions, compressions and displacements in the implants and supporting structures.

For these reasons, a study was designed using 3D FEA model that could analyze the biomechanical behavior of implants and prosthetic components that support a mandibular complete denture. With this purpose, it is intended to contribute for the understanding of the consequences of the tensions generated to the implants and supporting structures, simulating physiological conditions in different disocclusion patterns (canine guide and bilateral balance occlusion).

MATERIAL AND METHODS

Using SolidWorks® Office Premium 2006 software, three-dimensional models were drawn, simulating a mandibular complete denture supported by 5 Brånemark-type implants as pillars, located in the intra-mental foramen region. A complete denture with nickel-chromium metallic framework was designed with 12 acrylic denture teeth (from the mandibular left first molar to the mandibular right first molar) and a small gingival band in heat-cured acrylic resin without contact with mucous tissue, maintaining a 3-mm area for cleaning. The 5 titanium implants were distributed in the intra-mental foramen region, respecting a distance of 4 mm between its platforms. All implants were cylindrical (13 mm high x 3.75 mm diameter) with external hexagon and 4.1 mm platform. The simulated prosthetic components presented 3 mm of height and 4.1 mm platform. The prosthetic components were fabricated in titanium and were installed with 20 N torque in order to ensure good fitting.

The nickel-chromium metallic framework was simulated with a thickness of 6 mm, height of 4 mm and a total length of 58.75 mm, which provided a distal extension of 12 mm in each end. Around this framework, the gingival portion was drawn in heat-cured acrylic resin and 12 acrylic denture teeth were placed. The coefficient of Poisson (v) and the Modulus of elasticity (E) of each one of the distinct elements that composed the models were determined according to the literature, being spongy alveolar bone 1.370 MPa (E) and 0.30 (v); cortical alveolar bone 13,700 Mpa (E) and 0.30 (v); nickel-chromium alloy 188,000 MPa (E) and 0.28 (v); titanium (E) and 0.35 (v) and acrylic resin 2.700 MPa (E) and 0.35 (v). The disocclusion patterns were simulated applying a 15 N load at 45° angle.

Data were collected in points throughout the nickel-chromium framework, totalizing 30 points distributed uniformly, starting from the cantilever in the working side (named point 1) and finishing in the endpoint of the cantilever of the balancing side (named point 30). The results were analyzed comparing the magnitude of displacement in each one of the simulations. It is important to consider that the magnitude of the displacement mentions the vectorial average of the displacements in the main axes (x, y and z). The values were presented graphically to facilitate the comparison of data.

RESULTS

The results obtained in the analysis of tension distribution in the metallic framework, the prosthetic components and the implants, when the canine guide disocclusion was used, are demonstrated in Figures 1 and 2. It is important to comment that the program generates the images with

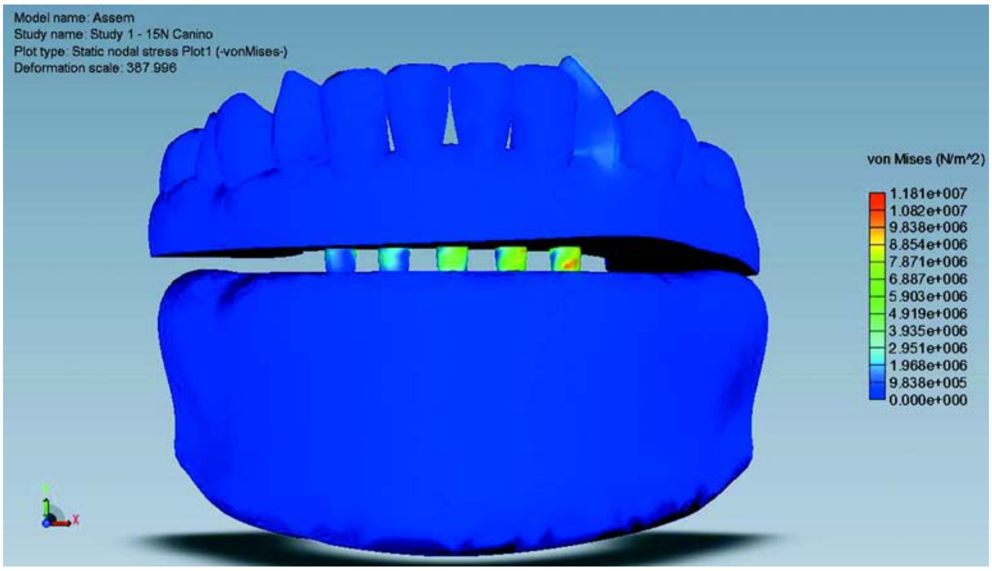

FIGURE 1- Disocclusion in canine guide

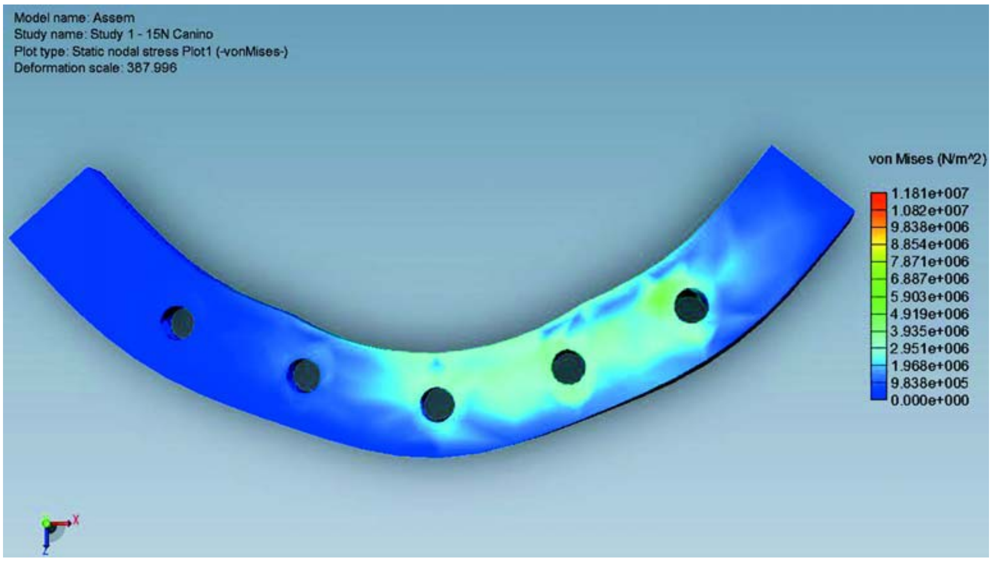

FIGURE 2- Disocclusion in canine guide, anterior view

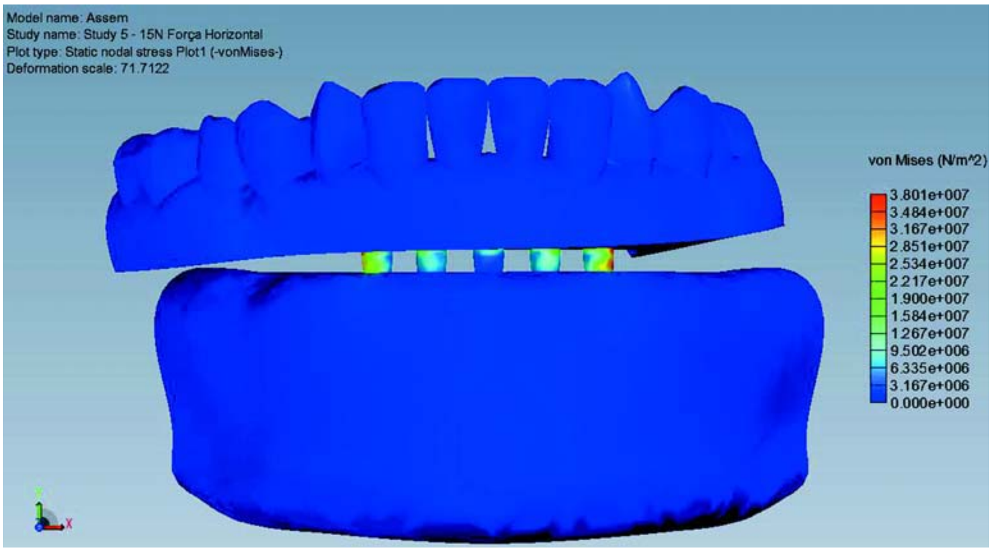

FIGURE 3- Bilateral balanced occlusion

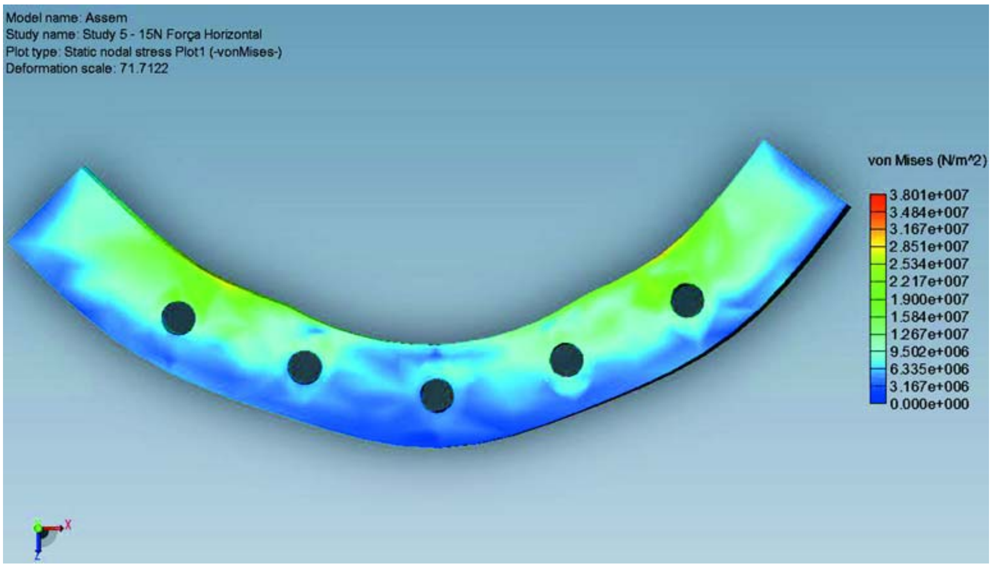

FIGURE 4- Bilateral balanced occlusion, anterior view

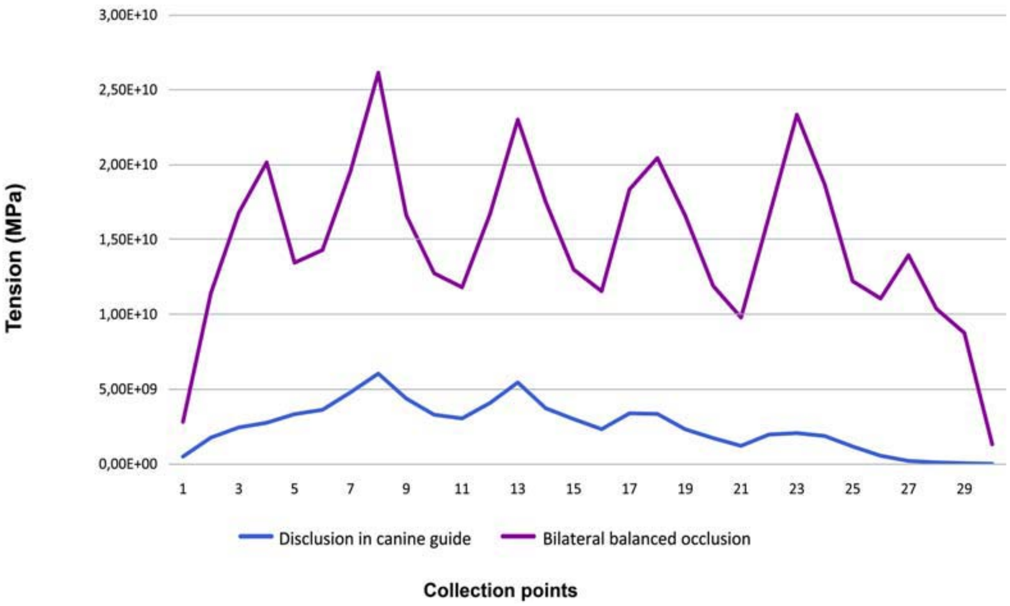

FIGURE 5- The data obtained on the collection points distributed throughout the metallic framework

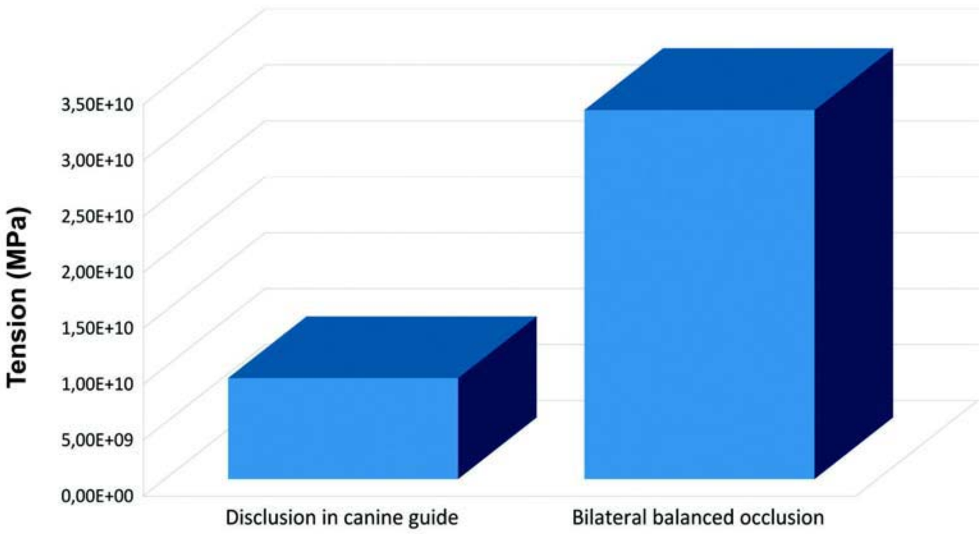

FIGURE 6- Value of maximum tension found in the simulation of disocclusion

exaggerated displacements with intention to facilitate the visualization.

The results obtained in the analysis of tension distribution in the metallic framework, the prosthetic components and the implants, when the bilateral balanced occlusion was used, are demonstrated in Figures 3 and 4.

The disocclusion pattern applied to the three-dimensional models generated a series of data obtained for the collection points, distributed throughout the metallic framework. These data resulting in the graph presented in Figure 5.

The graph demonstrates that the behavior of absorption of the tensions generated for the pattern of disocclusion in canine guide presents values of tensions well softer than the referring graph to the bilateral balanced occlusion. We observe in all the collection points, throughout the metallic framework in nickel-chromium, the disocclusion in canine guide presents lesser values that of the bilateral balanced occlusion. Figure 6 shows that the value of maximum tension found in the simulation of the pattern of disocclusion in the canine guide was approximately 3.22 fold smaller than the value of maximum tension found in the simulation of the bilateral balanced occlusion.

DISCUSSION

Although authors frequently express their concern about dental occlusion, most studies limit the analysis of tension distribution to cantilever[2,6,16,18]. In addition, the majority of these studies disregard the material that covers the metallic framework, making the analysis directly through the cantilever2[3,30].

The review of the literature for this study, in search for concepts and philosophies on disocclusion patterns, led us to the beginning of the last century, more specifically to 1905, when Christensen[4] described the bilateral balanced occlusion, initiating a current, supported for several authors[7,8,12,13,21,28]. In the search for studies referring to the canine guide, we came to 1919, when Nagao[20] established the concepts for this disocclusion pattern, initiating a philosophy that has been followed by a number of authors[1,9,10,19,24,25].

The search for the initial concepts of the disocclusion patterns had the intention to clarify the definitions of these patterns used in tissue-supported complete denture and in tooth-supported fixed dentures, and establish the concepts for the disocclusion patterns used in implant-supported complete denture. While there are some works directed mainly to the analysis of occlusion for improvement of the prosthodontic support, again loads applied to cantilevers[31], there is a lack of studies referring to the disocclusion patterns, which was the focus of the present study. Implant-supported complete dentures are actually the union of the concepts of tissue-supported complete dentures and tooth-supported fixed dentures. However, regarding the disocclusion patterns, which current we must follow? We can either opt for the canine guide disocclusion, following the orientation of fixed prosthesis or the occlusal adjustments in the natural dentition, aiming at concentrating the tensions in a region that does not belong to the cantilever region or choose the bilateral balanced occlusion and the use of tissue-supported complete dentures, aiming at a better tension distribution and consequent denture balance.

Unfortunately, great part of the dentists, both general practitioners and prosthesists, choose most frequently the canine guide disocclusion because it is a simpler method than the bilateral balanced occlusion. It is perhaps the only reason for this choice.

The understanding of load distribution and tension generation within an implant-supported denture system needs a study that allows analyzing the levels of stress generated during the function. According to Spiekermann, et al.[27] (1995), the three-dimensional finite element analysis provide efficient and accurate results, allowing the calculation of the distribution and concentration of stresses, as well as the deformation of the components of the system through a computerized reading.

The concern with the distribution and absorption of the tensions generated for occlusion and disocclusion patterns in an implant-supported denture must be treated with sufficient care and attention.

Since the introduction of the concept of osseointegration in a world-wide scale in 1982, one of the principles applied to the implant-supported dentures is that the implant would be protected of the impact produced by the occlusal function and mainly of parafunctional habits[3,26].

The success and longevity of implants are related to the mechanical factors, and tensions exceeding the physiological limits have been suggested as the primary causes of the initial periimplant bone loss[18].

The stress reduced around of the implants can result in atrophy for disuse, similar the bone loss in the alveolar crest after a tooth extraction. On the other hand, high concentrations of stress can result in pressures of necrosis and subsequent imperfection in the implant[17].

Occlusion can be considered an essential factor for the success of implant-supported dentures as well as for all procedures in restorative and prosthetic dentistry. Knowledge of occlusion is necessary for all dental specialties.

For osseointegrated implants, biomechanics has a special meaning, as natural teeth and implants have different anchorages in the bone. The treatment with implants can vary considerably and so it is almost impossible to establish a comparison between treatments. Two different approaches can offer a similar result in a short-term course. However, a biomechanical approach can determine which treatment presents more risks on long-term basis. If an implant-supported fixed denture is not well planned and adjusted, leaving some premature contact, or interference, the failure will be almost that inevitable[18].

Cusp-fossa oclusal contacts and/or reduction of cusp inclination, decreases the torque in the implant. When an oro-lingual occlusion is found, reducing the inclination of cusps, increases the distance of the bone crest, being able to produce undesirable torque. Crossbite contacts produce a resultant force close to the bone crest, reducing the torque[29].

Multi-element dentures with cantilever have occlusal stability due to the presence of multiple bilateral and simultaneous occlusal contacts, with a fast disocclusion preferably using the canine guide. This disocclusion pattern is chose not for being better, but for being easier to reproduce in the denture and will make that the resultant tensions are distributed throughout the denture and its components, including, gold screw, prosthetic component and implant[15].

The results of the present study are in contrast with these findings. The distribution of the tensions in the canine guide disocclusion is concentrated in the region of the first and second implants, while in the bilateral balanced occlusion, the resultant tensions are distributed more uniformly throughout the framework. The ease or difficulty of using of one or another one technique is pertinent to each professional. However, the disocclusion pattern in canine guide should be preferred for providing better results by resulting in less generation of tension to the entire metallic framework.

CONCLUSION

It may be concluded that for complete dentures supported by Brånemark-type implants, the canine guide should be the disocclusion pattern of choice, being contraindicated the use of the bilateral balanced occlusion.

REFERENCES

1- Amico A. The natural functional occlusion of the teeth of man. J Prosthet Dent. 1961;11(5):899-915.

2- Assif D, Marshak B, Horowitz A. Analysis of load to transfer and stress distribution by an implant-supported fixed partial denture. J Prosthet Dent. 1996;75(3):285-91.

3- Brunski J. Dental biomaterials and biomechanics in implant design. Quintessence Int. 1988;3(2):87-97.

4- Christensen C. The problem of the bite. Dent Cosmos. 1905;47(10):1184-95.

5- Eskitascioglu G, Usumez A. The influence of occlusal loading location on stresses transferred to implant-supported prostheses and supporting bone: a three-dimensional finite element study. J Prosthet Dent. 2004;91(2):144-50.

6- Falk H, Laurell L, Lundgren D. Occlusal forces pattern in dentitions with mandibular implant-supported fixed to cantilever prostheses occluded with completes dentures. Int J Oral Maxillofac Implants. 1989;4(1):55-62.

7- Granger ER. Functional relations of the same stomatognathic system. J Am Dent Assoc. 1954;4(6):638-47.

8- Guichet DL, Yoshinobu D, Caputo AA. Interproximal effect of splinting and contact tightness on load to transfer by implant restoration. J Prosthet Dent. 2002;87(5):528-35.

9- Heartwell CM, Rahn N. The syllabus of complete dentures. 2 ed. Philadelphia: Lea & Febiger; 1974. p.197-206.

10- Jankelson B, Hofmann GM, Hendron J. The physiology of the stomatognathic system. J Am Dent Assoc. 1953;46(4):375-86.

11- Kramer A, Weber H, Benzing U. Implant and prosthetic treatment of the edentulous maxillae using the bar-supported prosthesis. Int J Oral Maxillofac Implants. 1992;7(2):251-5.

12- Kurt LE. Balanced occlusion. J Am Dent Assoc. 1954;4:150-67.

13- Landa JS. Biologic significance of balanced occlusion and balanced articulation in completes denture service. J Am Dent Assoc. 1962;65(4):489-94.

14- Lin CL, Wang JC, Kuo YC. Numerical simulation on the biomechanical interactions of tooth/implant-supported system under various occlusal forces with rigid/non-rigid connections. J Biomech. 2006;39(3):453-63.

15- Lundgren D, Falk H, Laurell L. The influence of number and distribution of occlusal cantilever contacts on closing and chewing forces in dentition with implant-supported fixed prostheses occluding with complete dentures. Int J Oral Maxillofac Implants. 1989;4(4):277-83.

16- Lundgren D, Laurell L. Natural biomechanical aspects of fixed bridgen work supported by teeth and endosseus implants. Periodontology 2000. 1994;4(1):23-40.

17- Meijer HAJ, Starmans FJM, Steen WHA, Bosman F. Loading conditions of endosseous implants in an edentulous human mandible: three-dimensional, finite element study. J Oral Rehabil. 1996;23:757-63.

18- Misch CE, Bidez MW. Implant-protected occlusion: the biomechanical rationale. Compendium. 1994;15(11):1330-4.

19- Motwani BK, Sidhaye AB. The need of eccentric balances during mastication. J Prosthet Dent. 1990;64(6):689-90.

20- Nagao M. Comparative studies on the bends of spee in mammals, with discussion of its relation you the form of the fossa mandibularis. J Dent Res. 1919;1(2):159-202.

21- Nairn RJ. Lateral and protusive occlusion. J Dent. 1973;1:181-7.

22- Ogawa T, Ogimoto T, Koyano K. Occlusal validity of the examination method of contact pattern relating you mandibular position. J Dent. 2000;28(1):23-9.

23- Orsier JF. Local biomechanical analysis of cantilevers implant systems. J Oral Implantol. 1991;17:40-7.

24- Shaw DM. Form and function in the teeth. Int J Orthod. 1924;10(11):703-18.

25- Sheppard IM. Denture base dislodgment during mastication. J Prosthet Dent. 1963;13(3):462-8.

26- Skalak R. Biomechanical considerations in osseointegrated. J Prosthet Dent. 1983;49(6):843-8.

27- Spiekermann H; Donath K; Hassell T; Jovanivic S; Richiter, J. Biomechanics. color atlas of dental medicine implantology. New York: Thieme Medical Publishers; 1995. p. 81-90.

28- Trapozzano VR. Tests of balanced and nonbalanced occlusions. J Prosthet Dent. 1960;10(3):476-87.

29- Weinberg L. The Biomechanics of forces distribution in implant-supported prostheses. Int J Oral Maxillofac Implants. 1993;8:19-31.

30- White SN, Caputo AA, Anderkvist T. Effect of to cantilever length on stress to transfer by implant-supported prostheses. J Prosthet Dent. 1994;71(5):493-9.

31- Zampelis A, Rangert B, Heijl L. Tilting of splinted implants for improved prosthodontic support: a two dimensional finite element analysis. J Prosthet Dent. 2007;97(6):S35-S43.