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A Direct Digital Method for Measuring the Actual Biting Force Ondental Inclined Implants Using Novel Sensor

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Abstract

Introduction: *Common problems for edentulous patients, specially mandibular arch, include poor retention and stability, compromised function and comfort and low self-confidence and quality of life.*

Aim of the Work: *To described a new assembled digital device to device biting force of the patients in case of implant placement.*

Materials and Methods: *The novel sensor was used for measuring the clinical biting force of the patients after using the angulated implant retained over denture. To sense the patient biting force (BF) effectively, two sensors have been encapsulated into a conventional denture. When the patient bites on these sensors, their resistances vary according to mandibular BF. When the patient bites on the sensor, its resistance varies according to mandibular Biting force (BF). This variation was converted using the 555-timer circuit attached on the patient's clothing results in decreasing order of importance or chronologically.Nine complete edentulous patients were selected from Alexandria University. Patient age (50-60) years old and should be free from systemic diseases. For each patient maxillary complete denture and mandibular complete over denture supported by two 15° inclined implants with angulated locators was constructed.*

Results: *There was gradual increase of the marginal bone width of the residual supporting ridge throughout all the study periods at both the right and left implant sides in horizontal directions (bucco-lingual width), however, this increase was with no statistical significant difference (P = 0.491 for right and 0.964 for left) this increase in marginal bone is accompanied with increase in the bite force with increased performance and patient's satisfaction.*

Conclusions: *It was observed that there was no statistical significant difference between the right side when compared with the left side as regarding all the evaluating parameters (peri-implant ridge height, width, density and biting force) indicating more favorable stable implant supported overdeture with the use of inclined implants.*

Key Word: *Biting force, Inclined implant, Novel sensor, Computed tomography*

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I. Introduction

Implant-supported overdentures are the important, beneficial and helpful treatment for mandibular edentulous patients. Edentulous patient's major problem has been the lack of satisfaction with their complete dentures, especially the instability of the lower dentures. Osseointegrated dental implants are ideal treatment alternatives to enhance the retention and stability of the complete dentures[1].

Biting force evaluation

A key factor for the success or failure of a dental implant is the manner in which stress is transferred to the surrounding bone[2].

The need for reduction of traumatic forces transmitted through the prosthesis has long been recognized and studies have shown that either a soft acrylic resin/silicone rubber can serve as a stress distributor and absorb some of the forces applied to the teeth. These dentures permit reaction to impact forces which allows independent movement of one or more teeth in function unlike the conventional dentures[3].

Bite force (BF) results from the combined action of the jaw elevator muscles modified by jaw biomechanics and reflex mechanisms. The determination of individual bite force levels was done to understand jaw muscles strength, muscle function and activity and for evaluation of therapeutic effect of oral prostheses[4].

The most common technique for measuring BF was strain gages. Bite force is an important variable to investigate oral function related to occlusal factor, dentition, dentures, treatment with implants, orthognatic surgery, temporo-mandibular disorders and neuromuscular changes[5].

Muscle force and the number of functional teeth are determinant factors in masticatory. Measuring maximum bite force is an attempt to quantify the force that mandible elevator muscles can make[6].

Bite force (BF) results from the combined action of the jaw elevator muscles modified by jaw biomechanics and reflex mechanisms. The determination of individual bite force levels was done to understand jaw muscles strength, muscle function and activity and for evaluation of therapeutic effect of oral prostheses[7].

The most common technique for measuring BF was strain gages. They offer many advantages over other techniques such as simple installation that can be carried out with little training, available circuitry to measure its linear output over a large range of forces because of its easy estimation of the magnitude of the gage output with little well defined calculations. However, the resistance strain gages have their limitations. One of the most important limitations is the large size of the gauge applied to BF transducers. The large size of the gauges requires the height of the BF transducer to about 10 millimeters which causes a bite opening. This mouth opening will initiate a movement of the condyle along the articular eminence and therefore change the relationship to the closing muscles[8,9]. The non-linearity of human Biting Force (BF) provides a non-accurate computational analysis results. Recently the force sensing resistor, surface material of the sensor, and the computational software are important for determination of dental functional loading levels and increasing the medical analysis accuracy. Therefore, this research was conducted to record the biting force and electromyographic activity resulting from occlusal reactive mandibular implant overdenture opposed by natural dentition[7,10].

II. Materials and Methods

Nine completely edentulous patients were selected from Removable Prosthodontic Department, Faculty of Dentistry, Alexandria University. For each patient a maxillary complete denture and mandibular complete over denture retained by two inclined implants were fabricated and evaluated by clinical, radiographic, biting force measurement using novel sensor.

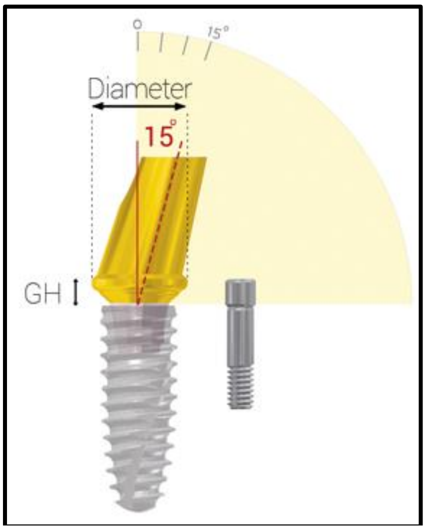
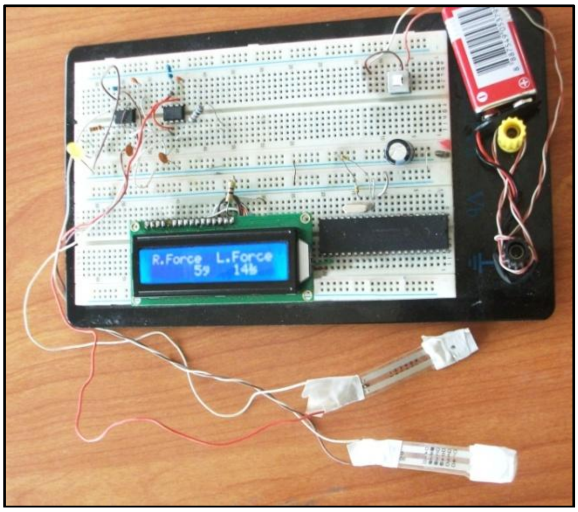


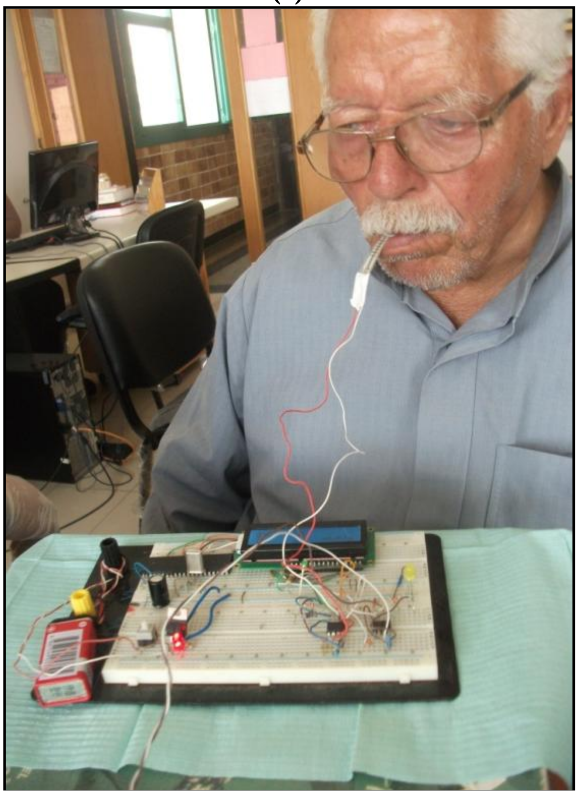
Fig. (1): Angulated locator 15° (superstructure)

Measuring the exacting biting force of the patient after using the inclined implants retaining mandibular over denture[7]

The novel sensor was used for measuring the clinical biting force of the patients after using the angulated implant retained over denture[11]. The patients were asked to bite on the biting sensing area at both sides for digital record of their applied biting force (Fig. 2). To sense the patient biting force (BF) effectively, two sensors have been encapsulated into a conventional bite guard which is safe. When the patient bites on these sensors, their resistances vary according to mandibular BF. These variations are converted using two Resistances to Frequency converter circuits, then their outputs are encoded and are coupled to decoder for next processing and readout.



(a)



(b)

Fig. (2 a,b): Novel sensor for biting force measurements.

The biting force measures were recorded at all the follow up periods (0, 3, 6 and 12 months of over denture use) and postoperatively, 3D CT scan evaluation were done at 3, 6 and 12 months post-loading at 6 , 9 and 12 months.

The data was sent to a remote measuring setup for treatment and analysis for repetitive measurement in time during the computed tomography (CT) procedures. These sent intra mouth data was transmitted remotely to external setup and validated by analysis that predicted the displacement of implant body (strains) through the patient bone versus the forces (strains) according to biting force measurements. When the patient bites on the sensor, its resistance varies according to mandibular Biting force (BF). This variation was converted using the 555-timer circuit attached on the patient's clothing results in decreasing order of importance or chronologically.

III. Results

Biomechanical evaluation (bite force measurement)

Mean and standard deviation of the exacting biting force of all patients of both sides were presented in (Table I and graph I).

At the both sides, there was a significant increase in the mean biting force at 1, 3, 6 and 1 year observation stages from the initial evaluation period. There was increase at the right side (19.6 - 37.3- 37.5-68.4) and also there was increase at the left side (25.3- 43.7- 44.4 - 59.4) with P value of 0.002 for right and 0.015 fore left. The maximum increase at the mean biting force was at 1 year observation period of right and left mean was (68.4) and (59.4) respectively.

At the right side, by comparing the biting force at 3 months Vs initial stage there was statistically significant increase with P value of 0.050 and by comparing of 6 months Vs initial stage which was also statistically significant increase with P value of 0.01, also after 1 year Vs initial it was more increase with P value of 0.001* and also while the P value at 6 months Vs 3 months was 0.524 which was statistically insignificant increase. P value at 1 year Vs 3 months was 0.042* which indicate a statistically significant increase, also at 1 year Vs 6 months was 0.44* which was statistically significant increase.

At the left side, by comparing the biting force at 3 months Vs initial stage P value was 0.099 which indicate statistically insignificant increase while by comparing the 6 months Vs initial stage was also statistically significant increase (P = 0.01) also after 1 year Vs initial there was more increase with P = 0.001. At 6 months Vs 3 months there was stable biting force with P = 0.663 which was statistically insignificant. At 1 year Vs 3 months the P value was 0.039* which was statistically significant increase. Also at 1 year Vs 6 months the P value was 0.039* which was statistically significant increase.

By comparing the biting force values at right side compared to left side the mean score of the left side were higher than at the right side but without significant values at all the study periods with P value of (0.624, 0.779, 0.351, 0.208) respectively.

Table no I: Biting force on the occlusal surface of all patients at both sides.

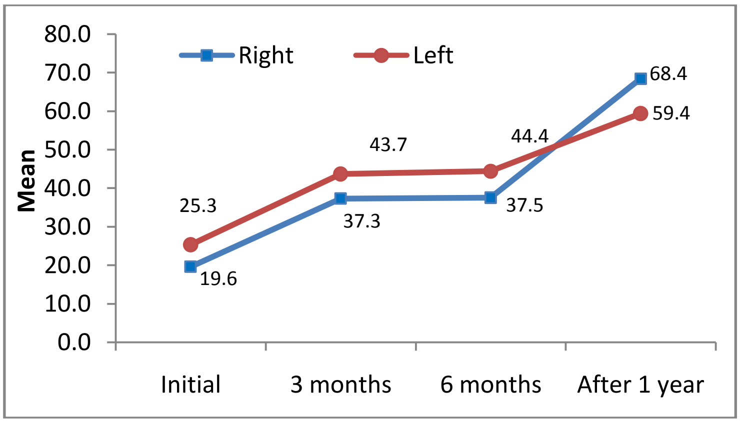
Bitting Force	Initial					3 months					6 months					After 1 year					P^+
Side	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	
Right	6.0	77.0	19.6	23.8	11.1	11.0	78.0	37.3	22.9	31.5	6.0	83.0	37.5	27.7	39.5	20.0	110.0	68.4	31.2	78.5	0.002*
Left	7.5	75.0	25.3	24.9	14.4	5.9	85.0	43.7	27.5	42.0	8.0	99.0	44.4	35.9	36.5	17.0	99.0	59.4	28.9	50.0	0.015*
P	**0.624**					**0.779**					**0.351**					**0.208**					
	Right										**Left**										
3 msVs Initial	0.050*										0.099										
6 msVs Initial	0.01*										0.010*										
1 year Vs Initial	0.001*										0.001*										
6ms Vs 3 ms	0.524										0.663										
1 year Vs 3 ms	0.042*										0.039*										
1 year Vs 6 ms	0.044*										0.039*										

p: p value based on Wilcoxon test for two related samples (comparison between right and left sides)

P^+: P value based on Friedman test for several related samples

* $P \leq 0.05$ (significant)

Contrast are done by using adjusted p value for pair wise comparisons



IV. Discussion

Sethiet al[12] found that the increase in biting force was directly related to the increase in masticatory efficiency. Also, he concluded that the proposed biosensor is safe for introrally application (in-vivo) without alteration of patient bites and for evaluation of the biomechanics of the prosthetic appliances[13].

In our study two conical shape type (dentium implant system) (lengths: 13mm, diameters: 4mm) were used, which provide tapered load distribution, achieve excellent bone response, harmonize with surrounding bone anatomically, the large surface area provide excellent initial stability[14,15].

Two angulated locator 15° (superstructure) design (Kerator) were used in this study because the locator attachment, (with a resilient overdenture attachment) is designed to retain tissue supported overdentures on 2 to 4 implants[16]. The self-aligning feature of the locator abutment allows patients to seat and remove the overdenture easily without damage to the attachments[17,18]. The locator abutment has the lowest vertical height of any resilient overdenture abutment[19].

Each implant was placed by 15° inclination to simulate the natural inclination of the canine which follow the hypothesis of reducing force magnitude by this inclination as: It was previously reported that the surrounding bone will be preserved, due to the wide spread of forces to the surrounding bone[20,21].

Tilting of posterior implants was previously studied. It was found that the bone-to-implant contact was enhanced, providing optimal bone support even with minimum bone volume[22]. Additionally, tilting of implants was tried in the maxilla and allowed for improved anchorage in a better quality anterior bone and bicortical anchorage in the cortical bone of the sinus wall and the nasal fossa as found by Mal, et al (2003)[23]. Tilting of the posterior implants also was investigated by other investigators who found that tilting protected the vital structures (such as the mandibular nerve or the maxillary sinus) and resulted in a better distribution of forces along the alveolar crest, which optimized load distribution[24,25].

On the reverse in other study for an implant placed under immediate loading to support a single-tooth restoration with abutment angulations up to 25 degrees showed increase of the stresses in the peri-implant bone[12,26-30].

In our study, it was found that there was a significant gradual increase by time in the mean biting force after 1, 3, 6 months and 1 year observation stages from the initial evaluation period with non-significant values between the two sides. This gradual increase may be attributed to the influence of implant inclination impact on implant survival and consequently improve the biting force gradually as founded by Eger et al.[27]

It was also reported that maximum biting force (MBF) in mandibular implant-supported overdenture patients was at least twice as much as that of conventional (complete denture) prosthetic patients[31] and this conclusion support our result of increasing biting force at all the follow up stages with better patient's satisfaction.

The bone density influence the amount of bone in contact with implant surface, not only at first stage surgery but also at second stage and early prosthetic loading[32-34] The same observation was found in our study as we found more increase of the bone density around the implants at all the follow up periods of prosthetic loading tell the end of one year follow up stage.

This observation can be attributed to the use of the inclined implants which increased the bone contact area and this could be the reason for the lower stress values around the inclined implant and in turn improve bone density as reported by (Misch[13], Stegaroiu)[35].

The finite element analysis in our study revealed that the 15 degree angulated implant and locator (simulating natural canine inclination) when the force was directed vertically to it would be broken down when meet such inclined and serrated implant surfaces that counteract the absence of periodontal ligament of the natural teeth surfaces[21], so it will be converted to strain accordingly the magnitude of the stresses decreased more than that directed to vertical implant and straight abutment[20].

This results disagree with Kao et al[29] who concluded that the abutmrnt angulation up to 25 degree can increase the stresses in the peri-implant bone by 18% and the micromotion by 30 percent. It could be attributed to the geometrical and fact that the design of the angulated abutments and serration of the implant surface increasing the path way of the stresses to reach the pre-implant area to be converted into strain that decrease in its magnitude as it passes epically.

The Same results were found in a finite element stress analysis study by Gul and Suca[1] who reported that connected tilted implants had better stress distribution than vertical implants and they suggested that mesial inclination of implants were similar to the direction of the occlusal forces.

On the contrary, some other finding concluded that changing the angulation of an implant resulted in the increase of the stress magnitudes. These findings agree with other reports stating that having an angled implant or abutment is less favorable for stress distribution[36-39].

John et al,[40] concluded that the greatest stress concentrations were seen at the crest of the cortical bone and could be reduced by using smaller sized attachments for implant supported-overdenture and this finding can explain our results of reduced stress around the neck of the implant near the crest of the alveolar ridge due to use smaller and angulated locator attachment.

Fastier-Wooller et al.,[41] used a novel low-cost sensor for human bite force measurement and it was concluded that the results presented herein demonstrate the simple and user-friendly fabrication of a novel, economical bite force sensor using an acrylic structure with a bonded metal strain gauge which is agree with Lin et al.[42]

Amid et al.,[43] studied the clinical evaluation of a new device to measure maximum bite force, it was concluded that the designed device had adequate accuracy. It has uniqueproperties such as an external sensor, which is replaceable and can bedisinfected and also a digital port. It has the ability to measure maximum andsub-maximum masticatory loads and the possibility to depict them in a graph which agrees with our results.

All these studies indicated a good osteointegration between bone and inclined implant surfaces with increase in stability. The same observation was found in our study which also indicated a good oesteointergration between bone and inclined implant surface as observed by the favourable uses of both sides efficiently for biting and food mastication, also, by the increasing of marginal bone height around the implants in horizontal direction (bucco-lingual width) and in vertical direction measurement (bone height at vertical residual bone of inclined line at 15° measurement).

V. Conclusions

- Biomechanical measurements of the bite force showed favorable increase at all observation stages with increased performance at the end of the follow up period.
- It was observed that there was no statistical significant difference between the right side when compared with the left side as regarding all the evaluating parameters indicating more favorable stable implant supported overdeture with the use of inclined implants.
- There was little increase in the residual supporting ridge throughout all the study periods at both the right and left implant sides in bucco lingual direction.
- All this observations were be further investigated and confirmed in conductive future study using finite element analysis.

References

[1]. Gul EB, Suca GC. Finite Element Stress Analysis of Overdentures Supported by Angled Implants. Merit Res J Med MedSci 2014;2:196-206.
[2]. Rieger MR, Adams WK, Kinzel GL, et al. Finite element analysis of boneadapted and bone-bonded endosseous implants. J Prosthet Dent 1989;62:436-440.
[3]. Shen WL, Chen CS, Hsu ML. Influence of implant collar design on stress and strain distribution in the crestal compact bone: a three-dimensional finite element analysis. Int J Oral Maxillofac Implants 2010;25:901-910.
[4]. Geng JP, Tan KB, Liu GR. Application of finite element analysis in implant dentistry: a review of the literature. J Prosthet Dent 2001;85:585-598.
[5]. Erkmen E, Meriç G, Kurt A, et al. Biomechanical comparison of implant retained fixed partial dentures with fiber reinforced composite versus conventional metal frameworks: a 3D FEA study. J MechBehav Biomed Mater 2011;4:107-116.
[6]. Brånemark PI, Adell R, Breine U, et al. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J PlastReconstrSurg 1969; 3: 81-100.
[7]. Fernandes CP, Glantz PF, Svensson ST, et al. A novel sensor bite force determination. Dent Mater 2003;19:118-26.
[8]. Ortu G. A new device for measuring mastication force. Ann Anat 2002;184:393-396.
[9]. Gibbs CH, Mahan PE, Mauderli A, et al. Limits of human bite strength. J Prosthet Dent 1986;56:226-229.
[10]. Tayel M, Elaskary S, Tamer N. A bio-sensory system for increase implant longevity for occlusal analysis. 2nd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA). Beirut, 12-15 December 2012, 7-10.
[11]. El-Askary SAH. Performance of ultra-wideband signals in interference environments. M.Sc. Thesis. Electrical Engineering Department, Faculty of Engineering, Alexandria University. 2008.
[12]. Sethi A, Kaus T, Sochor P. The use of angulated abutments in implant dentistry: Five-year clinical results of an ongoing prospective study. Int J Oral Maxillofac Implants 2000;15:801-810.
[13]. Misch CE. Contemporary implant dentistry. 3rd ed. St. Louis: Mosby; 2007.
[14]. ChungKH, ChungCY, CagnaDR, et al. Retention characteristics of attachment systems for implant overdentures. J Prosthodont 2004;13:221-226.
[15]. Dentium. Simple Line II Surgical / Prosthesis Manual. 2013. Available at: http://www.dentium.com/USERFILES/BBSDATA/SimpleLineIIManual_1304_Rev.1_web.pdf.
[16]. Bilhan H, Mumcu E, Arat S. The comparison of marginal bone loss around mandibular overdenture-supporting implants with two different attachment types in a loading period of 36 months. Gerodontology 2011;28:49-57.
[17]. Alsaadi G, Quirynen M, Michiels K, et al. A biomechanical assessment of the relation between the oral implant stability at insertion and subjective bone quality assessment. J ClinPeriodontol 2007;34:359-366.
[18]. Meredith N, Alleyne D, Cawley P. Quantitative determination of the stability of the implant-tissue interface using resonance frequency analysis. Clin Oral Implants Res 1996;7:261-267.
[19]. Schulte W, Lukas D. The periotest method. Int Dent J 1992;42:433-440.
[20]. Pektaş O, Tönük E. Mechanical design, analysis, and laboratory testing of a dental implant with axial flexibility similar to natural tooth with periodontal ligament. ProcInstMechEng H 2014.
[21]. Steigenga JT, Al-Shammari KF, Nociti FH, et al. Dental implant design and its relationship to long-term implant success. Implant Dent 2003;12:306-317.

[22]. Assunção WG, Barão VAR, Gomes EA, et al. FEA in dentistry: A useful tool to investigate the biomechanical behavior of implant supported prosthesis. Finite Element Analysis - From Biomedical Applications to Industrial Developments. 2012. Available at: http://www.intechopen.com/books/finite-element-analysis-from-biomedical-applications-to-industrialdevelopments/fea-in-dentistry-a-useful-tool-to-investigate-the-biomechanical-behavior-of-implant-supportedprosth.

[23]. Mal ́P, Rangert B, de AråjoNobre M. "All-on-Four" immediate-function concept with Bronemark System implants for completely edentulous mandibles: A retrospective clinical study. Clin Implant Dent Relat Res 2003;5(Suppl 1):2-9.

[24]. Mal P, Rangert B, de AråjoNobre M. All-on-4 immediate-function concept with Branemark System implants for completely edentulous maxillae: A 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005;7(Suppl):88-94.

[25]. Kerator. Implant type. 2010. Available at: http://www.kerator.com/sub/ sub.html?oneNum=2&twoNum=1&threeNum=1.

[26]. Balshi TJ, Ekfeldt A, Stenberg T, et al. Three-year evaluation of Br nemark implants connected to angulated abutments. Int J Oral Maxillofac Implants 1997;12:52-58.

[27]. Eger DE, Gunsolley JC, Feldman S. Comparison of angled and standard abutments and their effect on clinical outcomes: A preliminary report. Int J Oral Maxillofac Implants 2000;15:819-823.

[28]. Sethi A, Kaus T, Sochor P, et al. Evolution of the concept of angulated abutments in implant dentistry: 14-year clinical data. Implant Dent 2002;11:41-51.

[29]. Kao HC, Gung YW, Chung TF, et al. The influence of abutment angulation on micromotion level for immediately loaded dental implants: a 3-D finite element analysis. Int J Oral Maxillofac Implants 2008;23:623-630.

[30]. Cardelli P, Montani M, Gallio M, et al. Angulated abutments and perimplants stress: F.E.M. Analysis. Oral Implantol (Rome) 2009;2:3-10.

[31]. Escudeiro SC, Freitas O, Spadaro ACC, et al. Development of a colorimetric system for evaluation of the masticatory efficiency. Br Dent J 2006;17:95-99

[32]. Misch CL, Increasing the Density of Bone with a Prosthetic Protocol. Ch 32. 1990. Available at: http://pocketdentistry.com/32-progressive-bone-loading/#bib13

[33]. Misch CE. Density of bone: effect on treatment plans, surgical approach, healing, and progressive boen loading. Int J OralImplantolImplantologist 1990;6:23-31.

[34]. Mahaseth P, Shetty S, Babu C, et al. Peri-implant stress analysis of immediate loading and progressive loading implants in different bone densities (D2 and D3): A finite element study. Int J Oral ImplantolClin Res 2014;5:1-7.

[35]. vanZyl PP, Grundling NL, Jooste CH, et al. Three dimensional finite element model of a human mandible incorporating six osseointegrated implants for stress analysis of mandibular cantilever prostheses. Int J Oral Maxillofac Implants 1995;10:51-57.

[36]. Watanabe F, Hata Y, Komatsu S, et al. Finite element analysis of the influence of implant inclination, loading position, and load direction on stress distribution. Odontology 2003;91:31-36.

[37]. Canay S, Hersek N, Akpinar I, et al. Comparison of stress distribution around vertical and angled implants with finite-element analysis. Quintessence Int 1996;27:591-598.

[38]. Brosh T, Pilo R, Sudai D. The influence of abutment angulation on strains and stresse along the bone implant interface: comparison between two experimental techniques. J Prosthet Dent 1998;79:328-334.

[39]. Frederick DR, Caputo AA. Effects of overdenture retention designs and implant orientations on load transfer characteristics. J Prosthet Dent 1996;76:624-632.

[40]. John J, Rangarajan V, Savadi R, et al. A finite element analysis of stress distribution in the bone, around the implant supporting a mandibular overdenture with ball/o ring and magnetic attachment. ResearchGate.

[41]. Fastier-Wooller J, Phan HP, Dinh T, et al. Novel Low-Cost Sensor for Human Bite Force Measurement. Sensors (Basel) 2016;16. pii: E1244.

[42]. Lin KR, Chang CH, Liu TH, et al. Experimental and numerical estimations into the force distribution on an occlusal surface utilizing a flexible force sensor array.JBiomech 2011;44:1879-1884.

[43]. Amid R, Ebrahimi N, Kadkhodazadeh M, et al. Clinical evaluation of a new device to measure maximum bite force. Dentist Case Rep 2018;2:26-29.

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