Acta Odontologica Scandinavica, 2013; 71: 1181–1187

informa
healthcare

ORIGINAL ARTICLE

In vivo evaluation of occlusalcontact area and maximum bite force in patients with various types of implant-supported prostheses

EMRAH BACA[1], ESENGN YENGIN[1], BILGE GÖKÇEN-RÖHLIG[1] & SUICHI SATO[2]

[1]*Department of Prosthodontics, Faculty of Dentistry, Istanbul University, Istanbul, Turkey, and* [2]*Department of Oral and Maxillofacial Surgery, School of Dentistry, Tohoku University, Sendai, Japan*

Abstract

Objective. To determine the effects of various implant retained and/or supported prostheses on number of occlusal contacts (NOC), occlusal contact area (OCA)and maximum bite force (BF). ***Patients and methods:*** In total, 56 patients were included in the study; five test groups and two control groups. The patients in the treatment groups received implant-supported/retained prosthesis; over-dentures retained with two individual attachments in occlusion with complete denture, with four individual attachments in occlusion with complete denture, with four individual attachments in occlusion with fixed partial dentures or natural dentition, 6-implant retained fixed bridges in occlusion with natural dentition and 8-implant retained fixed bridges in occlusion with natural dentition. The patients in control group 1 were wearing conventional complete maxillary and mandibular dentures, whereas in control group 2 they had fixed full-arch porcelain-fused to metal restorations prostheses for both arches. Dental Pre-scale was used measure the NOC, BF and OCA. ***Results.*** There was no statistically significant difference between the treatment and control groups, among the groups with regards to NOC. OCA demonstrated different results among the removable and fixed reconstruction groups. With regards to BF, removable dentures supported with four implants showed higher bite force values than controls and two implant over-dentures. Also, a fixed reconstruction using eight implants showed higher BF values than a fixed reconstruction using six implants. ***Conclusion.*** Use of implants for removable dentures and fixed reconstructions improve occlusal contact area and bite force.

Key Words: *bite force, implant, prosthesis*

Introduction

The loss of natural teeth is related to diminished nutritional intake, especially in older adults. A number of studies have shown that the masticatory performance of edentulous patients wearing complete dentures is ~ 10–20% as efficientas that of dentate subjects [1]. The treatment of edentulous patients is always a challenge for the prosthodontist. The restorative procedures for edentulous patients consist of various phases that aim to reconstruct and replace the loss of the natural dentition and the associated structures of both the mandible and maxilla [2].

In the past, the treatment of choice for completely edentulous patients was a removable complete denture prosthesis. Over the course of time, removable dentures can promote or even contribute to bone resorption ofboth jaws. The loss of osseous denture support can render a patient unable to adequately wear a denture. When total edentulism occurs and bone resorption continues over time, a relative procumbance of the mandible can occur. The loss of intra-oral muscle attachments can interfere with the function of dentures [3]. Implant prostheses offer the possibility of overcoming some of the functional limitations of complete dentures. Patients who had problems with dentures and received implant prostheses showed improved chewing ability and food selection after the provision of satisfactory implant-stabilized and conventional complete dentures [1].

The currently available evidence suggests that the restoration of the edentulous mandible with a conventional denture is no longer the most appropriate first choice for prosthodontic treatment. There is now overwhelming evidence that a two-implant overdenture is a more favorable choice of treatment for the

Correspondence: Bilge Gökçen-Röhlig, Department of Prosthodontics, Faculty of Dentistry, Istanbul University, Capa34390 Istanbul, Turkey. Tel: +902125312230. Fax: +902125312230. E-mail: bgokcen@istanbul.edu.tr

(Received 8 July 2012; revised 22 September 2012; accepted 26 November 2012)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2012.757360

edentulous mandible [4]. In the treatment of edentulous arches, various treatment concepts with dental implants are being developed, including the treatment of edentulous arches with two-to-nine implants and with implant supported/retained removable or fixed prosthesis [5,6].

The measurement of bite force is often necessary toassessthe jaw-closing muscle function and also to compare the muscle activity between subjects in a wide variety of experimental situations [7]. Some investigators have suggested that the occlusal contact area, occlusal pressure, bite force and masticatory efficiency could be useful for the understanding of masticatory function in patients with orofacial problems [8].There are no longitudinal studies on the bite force with implant-supported/retained over-dentures with follow-up periods beyond 1 year; furthermore, bite force studies often do not allow for satisfactory comparisons between implant-retained over-dentures and fixed-implant bridges due to differences in methodology and patient selection. Therefore, the influence of differences in implant support for mandibular over-dentures on bite force is still unknown [9].

The aim of this study was to determine the effects of various implant-retained and/or -supported prostheses on the maximum bite force (BF),the number of occlusal contacts (NOC)and the occlusal contact area (OCA). The authors hypothesized that the denture type has an effect on BF, NOC and OCA; the group that received fixed implant-supported reconstruction would demonstrate higher values than the groups that received conventional and implant-supported removable dentures.

Materials and methods

Patient selection

Between January 2007 and January 2009, 60 patients (32 men, 28 women, age range of 49–64 years) were included in the study. The patients were consecutively selected among the patients that reported to the Department of Prosthodontics in the Faculty of Dentistry, Istanbul University, for prosthodontic treatment. They all requested implant-supported and/or implant-retained restorations. The inclusion criteria were(1) complete edentulismat least in one arch; (2) between 45–65 years of age; (3) hadundergone tooth extraction at least 3 months prior to implant placement; (4) a proper maxillary–mandibular relationship; (5) absence of periodontal problems; (6) absence of alcohol and drug abuse; (7) no clinical and radiographic evidence of pathology; and (8) no history of radiation or ablative surgery related to orofacial tumors. Exclusion criteria were(1) any systemic disorders that can complicate the hard and soft tissue healing of osseointegrated implants (cardiovascular disorders, uncontrolled diabetes, rheumatoid diseases, psychiatric disorders, radiotherapy and bruxism); (2) history of musculoskeletal problems that could possibly affect masticatory muscles; (3) requirement of a hard or soft tissue graft before or in conjunction with implant placement; or (4) alcohol or drug abuse.

The Ethics Committee of the Istanbul University, Istanbul Faculty of Medicine, approved the protocol (2009/930). Written informed consent was obtained from each subject after a full explanation of the study.

Of the 60 patients, all signed the consent form,but four were excluded from the study because they did not regularlyattend the appointments.Forty subjects were chosen for treatment groups and 16 subjects for control groups. The patients were divided into treatment and control groups according to the number of implants used, withfive test groups and two control groups. Each group consisted of eight patients.

- *Treatment Group 1* (TG1): The patients were edentulous in both arches. In this group, patients received implant-retained and tissue-supported prostheses. Two implants were placed in the intraforaminal region in the mandible and the prostheses were restored with singular attachements (Locater abutments (Zest Anchors, Inc., CA Escondido, Distributor; InstitutStraumann AG Basel, Switzerland)). The opposing arch was restored with a complete denture. Bilaterally balanced occlusion was employed.
- *Treatment Group 2* (TG2): The patients were edentulous in both arches. In this group, patients also received implant-retained and tissue-supported prostheses. Four implants were placed in the intraforaminal region in the mandible and the pre-maxillary region in the maxilla. The prostheses were also restored with singular attachments (Locater abutments (Zest Anchors, Inc., Distributor; InstitutStraumann AG Basel)). The opposing arch was restored with a complete denture. Bilaterally balanced occlusion was employed.
- *Treatment Group 3* (TG3): The patients were edentulous in one arch and the opposite arch had complete dentition or was restored with fixed full-arch porcelainfused to metal restorations. In this group, patients also received implant-retained and tissue-supported prostheses. Four implants were placed in the intraforaminal region in the mandible and pre-maxillary region in the maxilla. The prostheses were restored with singular attachements (Locater abutments (Zest Anchors, Inc., Distributor; InstitutStraumann AG Basel)), too. Bilaterally balanced occlusion was employed.
- *Treatment Group 4* (TG4): The patients in this group were restored with cemented implant-retained fixed prostheses. In total, six implants were inserted in the regions of thecanine, the first or second premolars and the first molar. The opposing arch was restored with fixed full-arch

Figure 1. Dental pre-scale.

porcelainfused to metal restorations. Based on the patient, canine guidance or group function was established in this group.

- *Treatment Group 5* (TG5): The patients in this group received cemented implant-retained fixed prosthesis. In total, eight implants were inserted in canine, first premolar, second premolar and second molar regions. The opposing arch was restored with fixed full-arch porcelainfused to metal restorations. Based on the patient, canine guidance or group function was instituted.
- *Control Group 1* (CG1): All patients wore conventional complete maxillary and mandibular dentures for at least 1 year. Bilaterally balanced occlusion was applied.
- *Control Group 2* (CG2): All patients had fixed full-arch porcelainfused to metal restorations prostheses in both arches. Based on the patient, canine guidance or group function was created.

Measurement of OCA, OP and BF

In the first month after the prosthetic treatment and routine controls, the number of occlusal contacts (NOC), occlusal contact area (OCA) and bite force (BF) were measured by a type 50 H Dental Prescale (Fuji Photo Film Corporation, Tokyo, Japan). The Dental Pre-scale (Figure 1) consists of two paper sheets and numerous microcapsules,which contain a red dye. When the patients are asked to occlude (Figure 2), these microcapsules rupture and discharge the dye, staining one of the papers red. The density of the color is proportional to the degree of pressure applied. All measurements were made with the subject seated with the head upright, looking forward and in an unsupported natural head position. The patient was instructed to bite as forcefully as possible. The tooth contact area and the density of the color forocclusal pressure, as recorded on the Dental Prescale, were measured by an Occluzer FPD703 (Fuji Photo Film Corporation). The bite force was also calculated using this apparatus (Figure 3).

Statistical analysis

The statistical analyses were performed with the SPSS Statistical Program Package for Windows (SPSS, Chicago, IL). Differences in the OCA, NOC, BF and gender between patients and the control groups were evaluated. Descriptive statistical methods (mean, SD, IQR (interquartile range)) were used for the evaluations. The Kruskal-Wallis test was used for comparison between the groupsand Dunn's post-hoc test was used for the comparison of sub-groups. The significance level was set at $p = 0.05$.

Results

There were no statistically significant differences in age and gender between the treatment and control groups (Table I).

Number of occlusal contacts

The number of occlusal contacts did not differ between the groups (Table II). In sub-group comparisons, no difference was observed among the removable (Table III) and fixed reconstruction groups (Table IV).

Occlusal contact area

OCA demonstrated statistically significant differences betweenthe groups ($p = 0.0001$) (Table V). The

Figure 2. *In-vivo* measurement.

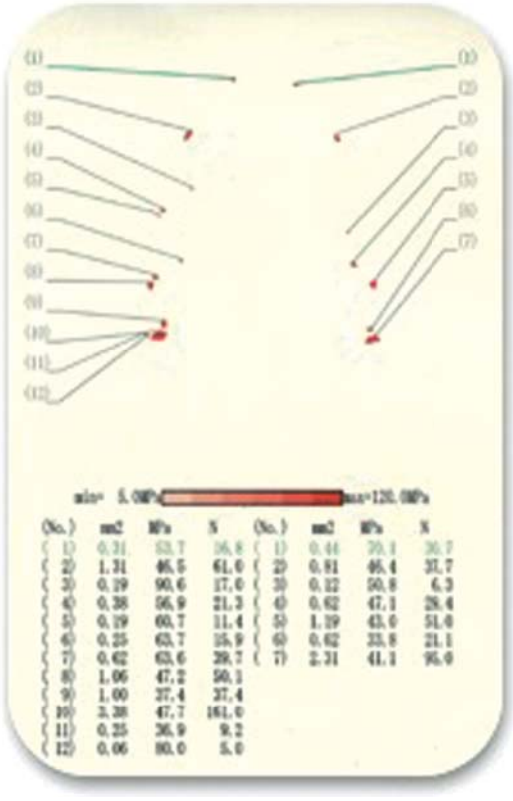

Figure 3. *In-vivo* measurement results.

Dunn's multiple comparison test values for OCA showed that CG1 had lower scores than TG2, TG2, TG3, TG5 and CG2 (Table VI). The other groups demonstrated no statistically significant difference between them ($p > 0.05$).

Maximum bite force

BF values showed significantly different results between the groups (Table VII). According to subgroup comparisons of the removable reconstruction groups, CG1 demonstrated significantly lower values than TG2 and TG3 ($p = 0.021$ and $p = 0.022$, respectively) (Table VIII). When the fixed reconstruction groups were compared with each other, TG4 had lower scores than TG5 ($p = 0.02$) (Tables IX and X). The other groups exhibited no significant differences($p > 0.05$).

Table I. Distribution of gender and age of the groups.

	Age (Mean)	Men (%)	Women (%)
TG1	55.75 ± 3.96	4 (50)	4 (50)
TG2	56.29 ± 5.09	4 (50)	4 (50)
TG3	56.75 ± 4.03	4 (50)	4 (50)
TG4	56.38 ± 4.44	4 (50)	4 (50)
TG5	56.25 ± 4.71	5 (62.5)	3 (37.5)
CG1	55.13 ± 4.97	4 (50)	4 (50)
CG2	55.13 ± 3.6	5 (62.5)	3 (37.5)
KW	0.88	0.982	
p	0.990	0.986	

Table II. Mean values of NOC were not statistically different among the groups ($p > 0.05$, 95% confidence intervals).

	Mean ± SD	Median (IQR)
TG1	21.62 ± 8.45	19.5 (15–26.75)
TG2	26.63 ± 7.04	24.5 (22.2–30.75)
TG3	25.62 ± 12.5	22.5 (16–38.75)
TG4	20.38 ± 6.41	19.5 (17–22.5)
TG5	19.13 ± 3.09	20 (15.5–21.75)
CG1	30.75 ± 22.08	17 (14.25–57.25)
CG2	27.38 ± 12.31	21.5 (17.5–41.5)
KW	4.97	
p	0.547	

Discussion

Simple, reliable methods for the quantification of masticatory function would be useful in evaluating the success of dental restorative procedures [10]. Assessment of the efficiency of masticatory function requires knowledge of the condition of all the parts of the stomatognathic system, as well as the magnitudes of bite force that represent the condition, expression and measure of the same function [11]. In this study, the measurement of bite force was used to determine the effects of various implant-retained and/or -supported prostheses on maximum bite force (BF),the number of occlusal contacts (NOC) and the occlusal contact area (OCA),which are determinants of masticatory function.

The measurement of bite force has been performed since the 1950s using bite forks, strain gauge transducers, electronic gnathodynamometers, digital dynamometers, pressure-sensitive sheets and occlusal analysis systems [12–15]. The reliability of intraoral bite force measurements remains questionable because these findings are difficult to compare [16]. Ithas been suggested that the highest bite force is achievedwhen the interocclusal space in the canine-molar regionis 9–20 mm [7,17]. Brunski [18]

Table III. Comparison of NOC in removable reconstruction groups.

	Mean ± SD	Median (IQR)
TG1	21.62 ± 8.45	19.5 (15–26.75)
TG2	26.63 ± 7.04	24.5 (22.2–30.75)
TG3	25.62 ± 12.5	22.5 (16–38.75)
CG1	20.38 ± 6.41	19.5 (17–22.5)
KW	3.52	
p	0.318	

Table IV. Comparison of NOC in fixed reconstruction groups.

	Mean ± SD	Median (IQR)
TG5	19.13 ± 3.09	20 (15.5–21.75)
TG6	30.75 ± 22.08	17 (14.25–57.25)
CG2	27.38 ± 12.31	21.5 (17.5–41.5)
KW	0.74	
p	0.691	

emphasized the importance of measuringloads on individual implants under non-axial closure and chewing forces with specially designeddevices. As these chewing forces can vary in dimension and shape, they may influence the accuracyof the bite force recordings. Only afew studies have reported the influence of the method (unilateral vs bilateral clenching) on the resulting bite force [19,20]. One study showed that, in healthy subjects, bite force increased ~ 100% and masseteractivity increased ~ 50% during bilateral clenching compared with unilateral clenching.As a consequence, a bilateral measuring system was employed to determine bite forces in this study.

A biteforce measuring system such as the Dental Pre-scale System, which uses a thin (~ 0.1 mm) pressure-sensitive film, is superior to ordinary measuringsystems that use strain-gauge transducers or other devices, for many reasons [10]. First, the biteforce can be measured close to the intercuspal position,which provides a better opportunity to estimate the biteforce under 'natural' conditions. Also in this position, most tooth contact occurs during mastication and the jawclosing muscles are capable of exerting the maximum masticatory force [21].Secondly, the load distribution over the dentition can also be studied multiple times. Matsuda et al. [22] used bilateral occlusal sheets because unilateral bite elements placed in the first molar region frequently dislodge removable dentures before a maximal occlusal force can be reached. There are several reasons why occlusal contacts in the intercuspal position are most likely involved in some critical stages of food breakdown. In this position, most tooth contact occurs during mastication and the jawclosing muscles are capable of exerting the maximum masticatory force [21]. Furthermore,the dental pre-scale system is able to measure occlusal forces with high accuracy within the range of 20–80 N, exclusive of 100 N [23]. In this study, we used Dental Pre-scale films to measure the bite force to utilize all of thesenoted advantages.

Matsuda et al. [22] performed bite force measurements 25 and 75 days after the replacement of new complete dentures andthey found statistically significant differences after the 25th day. Müller et al. [24] performed measurements in complete

Table V. Mean values of occlusal contact area (in mm) for all groups.

	Mean ± SD	Median (IQR)
TG1	10.59 ± 3,61	11.73 (6.56–12.41)
TG2	18.12 ± 9,68	16.26 (7.6–27.52)
TG3	18.34 ± 11,61	13.085 (9.02–26.21)
TG4	5.5 ± 2,13	4.99 (3.96–6.88)
TG5	16.44 ± 13,78	11.805 (9.52–15.47)
CG6	20.99 ± 10,93	16.41 (13.5–27.63)
CG7	18.97 ± 7.41	17.355 (14.17–25.97)
KW	24.91	
p	0.0001	

Table VI. Dunn's post-test values for OCA between sub-groups. Statistically significant lower scores were determined for CG1 than for TG2, TG3, TG5 and CG2. The other groups demonstrated no statistical difference between them ($p > 0.05$).

Dunn's post-test	OCA (mm^2)
TG1/ TG2	0.659
TG1/ TG3	0.655
TG1/ CG1	0.931
TG1/ TG4	0.874
TG1/ TG5	0.311
TG1/ CG2	0.568
TG2/ TG3	0.998
TG2/CG1	*0.045*
TG2/ TG4	0.999
TG2/ TG5	0.999
TG2/CG2	0.998
TG3/ CG1	*0.024*
TG3/ TG4	0.998
TG3/ TG52	0.998
TG3/CG2C	0.998
CG1/ TG1	0.255
CG1/TG2	*0.002*
CG1/ CG2	*0.01*

The italic scores shows the statistically different scores.

Table VII. BF scores for all groups (in N).

	Mean ± SD	Median (IQR)
TG1	416.29 ± 137.17	428.6 (294.4–532.1)
TG2	640.3 ± 249.06	746.8(335.5–860.5)
TG3	626.41 ± 367.89	478.05 (382.53–960.05)
TG4	254.85 ± 116.39	211.5 (179.23–336.43)
TG5	516.58 ± 85,58	506.95 (443.38–605.28)
CG1	841.24 ± 332,71	711.65 (638.6–1041.15)
GC2	685.24 ± 167.26	640.35 (557.88–865.05)
KW	27.85	
p	0.0001	

Table VIII. BF score comparisons for removable prosthesis.

	BF (N)
TG1/ TG2	0.292
TG1/ TG3	0.316
TG1/ CG1	0.541
TG2/ TG3	0.999
TG2/ CG1	*0.021*
TG3/CG1	*0.022*

The italic scores shows the statistically different scores.

dentures after assessing the old dentures and found that the greatest increase was observed within thefirst week after insertion.This clearly contradicts the results of Wöstmann et al. [25], who reported a preliminarydecrease in occlusal force in the first few days afterfitting. In the current study, bite force measurements were performed at the first month after the implant-supported prosthesis was inserted.

Helkimoet al. [12] compared the means of the bite force between genders and showed that these values were consistently higher for males. Ikebeet al. [26] also suggested that males exhibited significantly stronger bite force (511 N) than females (442 N). In this study, bite force was recorded as 563 N for males and 400 N for females with removable prostheses and 755 N for males and 576 N for females with fixed prostheses. These results positively correlate with those of past studies.

In the literature, several studies compare the masticatory performance of implant-supported removable prostheses by measuring the bite force [13,27]. Fontjin-Tekampet al. [27] determined that bite force is 139 N for a removable complete denture prosthesis and 235 N for a 2-implant-supported removable prosthesis. Rismanchian et al. [28] recorded a bite force of 5.6 kgf for a removable complete denture prosthesis and 12.2 kgffor a 2-implant-supported removable prosthesis. The results showed that implant-supported prostheses exhibited a bite force that was 2-times higher than that ofremovable complete dentures. In this study, the bite force recorded in removable complete dentures was 254 N and that

Table IX. BF scores for fixed prosthesis groups.

	Bite force (N)	
	Mean ± SD	Median (IQR)
TG4	516.58 ± 85.58	506.95 (443.38–605.28)
TG5	841.24 ± 332.71	711.65 (638.6–1041.15)
CG2	685.24 ± 167.26	640.35 (557.88–865.05)
KW	9.92	
p	0.007	

Table X. Comparisons of BF in fixed prosthesis groups.

	BF(N)
TG4/ TG5	*0.02*
TG4/CG2	0.298
TG5/ CG2	0.352

The italic scores shows the statistically different scores.

recorded in 2-implant-supported removable prostheses was 416 N. The results of this investigationpositively correlate with those of past studies.

Few studies have comparedthe bite forces in implant-supported fixed and removable prostheses. Lindquist and Carlsson. [29] studied the chewing effects of implant-supported fixed prostheses. After denture treatment, there was a significant increase in bite force. At the 3-year follow-up study, the mean value was almost 3-times greater than the first recorded value. That study also showed that the bite force was 254N in complete removable prostheses, 516N in 6-implant-supported fixed prostheses and 841N in 8-implant-supported fixed prostheses. The results of this study agree with those of Lindquist and Carlsson [29] study.

Tortopidiset al. [7] suggested that it is likely that the maximum force achieved was highly dependent on the number of posterior teeth that were loaded during the biting action. A studybyMotegiet al. [30] demonstrated that the patient's age is more important than the number of teeth when fewer teeth are present. According to this study, 6-implant-supported fixed prostheses had a lower bite force than 4-implant-supported removable prostheses. All of the 6-implant-supported fixed prostheses did not include the second molar teeth.

Within the limitations of this randomized-controlled clinical study, the following conclusions can be drawn:

- Regarding the occlusal contact area,

(1) The use of four implants for removable denture support, with or without an opposing fixed dentition, was superior to complete dentures without implants.
(2) The use of eight implants for fixed implant reconstruction or a complete dentition was superior to complete dentures without implants.

- Regarding the bite force,

(1) A fixed reconstruction using eight implants was superior to a removable prosthesis using two implants.
(2) A fixed natural dentition was superior to a removable prosthesis supported by four implants that opposed a natural dentition.

(3) Fixed reconstructions using six or eight implants are both superior to complete dentures without implants.
(4) A fixed natural dentition is superior to complete dentures.

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

References

[1] Allen F, McMillan A. Food selection and perceptions of chewing ability following provision of implant and conventional prostheses in complete denture wearers. Clin Oral Impl Res 2002;13:320–6.
[2] Hadjieva H, Dimova M. Total rehabilitation by edentulous patients with irregularity of the alveolar edges. J Int Med Assoc Bulgaria 2005;2:50–2.
[3] Flanagan D. An overview of complete artificial fixed dentition supported by endosseous implants. Artif Organs 2005;29: 73–81.
[4] Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani Set al. The McGill consensus statement on overdentures. Mandibular two-implant overdentures as first choice standard of care for edentulous patients. Gerodontology 2002; 19:3–4.
[5] Misch CE. Dental implant prosthetics. 1st ed. St Louis, MO: Elsevier Mosby Inc; 1993.
[6] Zarb GA, Bolender CL. Prosthodontic treatment for edentulous patients: complete dentures and implant-supported prosthesis. 12th ed. St. Louis, MO: Mosby Inc; 2004.
[7] Tortopidis D, Lyons MF, Baxendale RH, Gilmour WH. The variability of bite force measurement between sessions, in different positions within the dental arch. J Oral Rehabil 1998;25:681–6.
[8] Sato S, Ohta M, Sawatari M, Kawamura H, Motegi K. Occlusal contact area, occlusal pressure, bite force and masticatory efficiency in patients with anterior disc displacement of the temporomandibular joint. J Oral Rehabil 1999;26: 906–11.
[9] Fontjin-Tekamp FA, Slagter AP, Van't Hof MA, Geertman ME, Kalk W. Bite forces with mandibular implant-retained overdentures. J Dent Res 1998;77:1832–9.
[10] Manly RS, Braley LC. Masticatory performance and efficiency. J Dent Res 1950;29:448–51.
[11] Babic JZ, Panduric J, Jerolimov V, Mioc M, Pizeta I, Jakovac M. Bite force in subjects with complete dentition. Collegium Antropol 2002;26:293–302.
[12] Helkimo E, Carlsson G, Helkimo M. Bite force and state of dentition. Acta Odontol Scand 1977;35:297–303.
[13] Van Kampen FMC, Van der Bilt A, Cune MS, Bosman F. The influence of various attachment types in mandibular implannt-retained overdentures on maximum bite force and EMG. J Dent Res 2002;81:170–3.
[14] Bousdras VA, Cunningham JL, Bamber FPMA, Pedersen SS, Blunn G, Goodship AE. A novel approach to bite force measurements in a porcine model *in vivo*. Int J Oral Maxillofac Surg 2006;35:663–7.
[15] Hotta P, Hotta T, Bataglion C, Pavao R, Siessere S, Regalo S. Bite force in temporomandibular dysfunction (TMD) and healthy complete denture wearers. Braz Dent J 2008;19: 354–7.
[16] Roldan S, Buschang PH, Isaza-Saldarriaga JF, Throckmorton G. Reliability of bite force measurements in age-varying populations. JOral Rehabil 2009;36:801–7.
[17] Koç D, Doğan A, Bek B. Bite force and influential factors on bite force measurements: a literature review. Eur J Dent 2010; 4:223–2.
[18] Brunski JB. Biomaterials and biomechanics in dental implant design. Int J Oral Maxillofac Implants 1988;3:85–97.
[19] Shinogaya T, Bakke M, Thomsen CE, Villman A, Matsumoto M. Bite force and occlusal load in healty young subjects- a methodological study. Eur J ProsthodontRestor Dent 2000;8:11–15.
[20] Van der Bilt A, Tekamp A, Glas H, Abbink J. Bite force and electromyography during maximum unilateral and bilateral clenching. Eur J Oral Sci 2008;116:217–22.
[21] Hidaka O, Iwasaki M, Saito M, Morimotoi T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. J Dent Res 1999;78:1336–44.
[22] Matsuda K, Ikebe K, Ogawa T, Kagawa R, Maeda Y. Increase of salivary flow rate along with improved occlusal force after the replacement of complete dentures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:211–15.
[23] Shiga H, Kobayashi Y, Nakajima K, Yokoyama M, Arakawa I. Reliability of the occlusal force displayed on the dental prescale system. J Jpn Soc Stomatognath Funct 2003;9: 191–5.
[24] Müller F, Heath MR, Ott R. Maximum bite force after replacement of complete dentures. Gerodontology 2001;18: 58–62.
[25] Wöstmann B, Balkenhol M, Ferger P, Rehmann P. Changes in occlusal force at denture dislodgement after refabrication or optimization of complete dentures. Int J Prosthodont 2008; 21:305–6.
[26] Ikebe K, Nokubi T, Morii K, Kashiwagi J, Furuya M. Association of bite force with ageing and occlusal support in older adults. J Dent 2005;33:131–7.
[27] Fontjin-Tekamp FA, Slagter AP, Van't Hof MA, Geertman ME, Kalk W. Bite forces with mandibular implant-retained overdentures. J Dent Res 1998;77:1832–9.
[28] Rismanchian M, Bajoghli F, Mostajeran Z, Fazel A, Eshkevari PS. Effect of implants on maximum bite force in edentulous patients. J Oral Implantol 2009;4:196–200.
[29] Lindquist LW, Carlsson GE. Long-term effects on chewing with mandibular fixed prostheses on osseointegrated implants. Acta Odontol Scand 1985;43:39–45.
[30] Motegi E, Nomura M, Tachiki C, Miyazaki H, Takeuchi F, Takaku S, et al. Occlusal force in people in their sixties attending college for elderly. Bull Tokyo Dental Collague 2009;50:135–40.