Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden

Tactile sensitivity of vital and endodontically treated teeth

Birte-Juliane Schneider [a,1], Sandra Freitag-Wolf [b,2], Matthias Kern [a,*]

[a] Department of Prosthodontics, Propaedeutics and Dental Materials, School of Dentistry, Christian-Albrechts University at Kiel, Arnold-Heller-Str.16, 24105 Kiel, Germany

[b] Institute of Medical Informatics and Statistics, Christian-Albrechts University at Kiel, Brunswiker Str.10, 24105 Kiel, Germany

ARTICLE INFO

Article history:
Received 20 June 2014
Received in revised form
7 August 2014
Accepted 26 August 2014

Keywords:
Tactile sensitivity
Endodontically treated teeth
Tooth vitality
Removable partial dental prostheses
Humans
Gender

ABSTRACT

Objectives: Endodontically treated teeth (ETT) used as abutments for removable partial dental prostheses (RPDPs) have an increased fracture risk as compared to vital abutments. One suggested explanation is that ETT exhibit a lower threshold level for tactile sensitivity than vital teeth. Therefore, this study compared the threshold for tactile sensitivity of vital teeth and ETT in the same individuals.

Methods: Forty participants with double crown-retained RPDPs fixed to vital teeth and ETT were included in the study. Each subject had at least one vital and one corresponding contralateral endodontically treated abutment tooth in the same jaw. After removal of the RPDP, an increasing centric force (0 cN to max. 2000 cN) was separately applied axially to both free-standing abutment teeth using a force gauge while the patient was asked to give three acoustic signals: (1) when noticing the first contact, (2) when noticing pressure and (3) when the pressure became displeasing. Afterwards, the same trial was performed with an eccentric force applied parallel to the tooth axis.

Results: Statistical analysis revealed no significant differences in the threshold of tactile sensitivity of vital teeth and ETT to either centric or eccentric loading ($p > 0.05$). Eccentric loading showed lower mean threshold values compared to centric loading. A large variability of tactile sensitivity between individuals was noted. However, there were no gender-related significant differences in tactile sensitivity ($p > 0.05$).

Conclusions: The tactile sensitivity of vital and non-vital teeth seems comparable.

Clinical significance: The assumption that a lower threshold level for tactile sensitivity in ETT than in vital teeth is responsible for their increased fracture risk could not be confirmed. Therefore, other reasons, e.g. loss of hard tissue due to root canal treatment, have to be considered responsible for the increased fracture risk of ETT.

* Corresponding author. Tel.: +49 431 597 2874.
E-mail addresses: bi-u@gmx.de (B.-J. Schneider), freitag@medinfo.uni-kiel.de (S. Freitag-Wolf), mkern@proth.uni-kiel.de (M. Kern).
[1] Tel.: +49 17621982383.
[2] Tel.: +49 4315973180.

http://dx.doi.org/10.1016/j.jdent.2014.08.016

1. Introduction

A healthy periodontium has various neural receptors with distinct functions.[1] One function of the receptors in the periodontal ligament is the discriminatory ability of tactile and nociceptive sensitivity and the regulation of muscular activity.[2] The existence of intradental pressoreceptors has been documented and a higher threshold for pressoreceptive sensibility of ETT has been reported.[3]

Subjects with a removable partial or complete dental prosthesis have shown a reduced discriminatory ability compared to natural teeth.[4] In addition, there are receptors outside of the periodontium, for example, in the mucosa, the periosteum of the jaw bone, in the joints and muscle spindles, which seem to be important for mechanoreception and discriminatory ability.[1,5]

Active and passive assessments of thresholds of oral tactile sensitivity have been described. The passive threshold is determined by applying an increasing mechanical force to the tooth. The first sensation that is provoked with the minimal force is called the absolute threshold of perception.[6] The required loading for the first sensation on teeth is 1–10 cN.[7]

Endodontically treated teeth (ETT) used as abutment teeth for removable partial dental prostheses (RPDPs) have an increased fracture risk as compared to vital abutments.[8] One suggested explanation is that ETT exhibit a lower threshold level for tactile sensitivity than vital teeth.[9] Randow et al.[9] reported in 1986 that non-vital teeth have a reduced discriminatory tactile function with lower nociceptive responsiveness than vital teeth. However, they investigated only three subjects with one vital tooth and one ETT using cantilever loading. Results showed that the mean pain threshold level of non-vital teeth was twice as high compared to the level of vital teeth. However, this small clinical study seems to present a rather weak clinical evidence as only three subjects have been evaluated, resulting in an inadequate power of the study to draw reliable conclusions. Nevertheless, this unique experiment has been widely cited in the dental literature although these results have never been confirmed.

Various other reasons for the increased fracture risk of ETT have been discussed in the literature.[10–17] One obvious factor is the higher loss of tooth substance due to carious destruction and endodontic access cavity preparation in ETT. Additionally, the stress caused by endodontic procedures such as instrumentation, irrigation and obturation as well as the insertion of posts might introduce micro-cracks in non-vital teeth.[10–17] ETT with or without post-placement had a lower fracture resistance than vital teeth serving as RPDP abutments.[8,10,16,18,19] On average, 71% of fractured teeth were endodontically treated.[20,21] Often approximately 10 years after endodontic treatment vertical root fractures occured.[11,22]

In order to reveal whether a difference in tactile sensitivity of vital teeth and ETT might play a role in the increased fracture risk of ETT when serving as RPDP abutments, this study evaluated the passive threshold level for tactile sensitivity of vital teeth and ETT using centric and eccentric loading. The null hypothesis was that the tactile sensitivity of ETT does not differ from that of vital teeth.

2. Materials and methods

The study protocol has been approved by the Ethics Committee of the Christian-Albrechts University at Kiel, Germany. Forty participants (24 males, 16 females) were recruited from the Department of Prosthodontics, Propaedeutics and Dental Materials, Christian-Albrechts University at Kiel. All recruited participants gave their informed consent to participate in the study and defined insurance policy was contracted for all participants to cover possible risks for the loaded abutment teeth, such as tooth fracture.

Each subject had at least one vital and one endodontically treated abutment tooth supporting a double crown-retained RPDP. Matched abutment teeth in the same jaw were compared, i.e. incisor to incisor, canine to canine, premolar to premolar and molar to molar.

Inclusion criteria for selected test teeth were a healthy periodontium with a probing depth of maximum 3 mm, no bleeding on probing, a mobility of 0–1,[23] normal response of vital teeth when tested with CO_2 snow, stable bone level with a maximum of one-third bone loss and a root canal filling of sufficient quality. The quality of a root canal treatment was deemed sufficient if there were no clinical symptoms such as pain on bite or percussion and there was no evidence of pathologic changes in the periodontal ligament. Also the root canal filling had to be of appropriate density and extension within 1 mm of the radiographic root length.

After removal of the double-crown retained RPDP for reproductive eccentric loading an extension bar (CoCrMo, $10 \times 9 \times 2$ mm) was individually adapted to each abutment tooth in a right angle to its labial surface by underlining its annular opening with autopolymerizing composite (Luxatemp, DMG Chemisch-Pharmazeutische Fabrik GmbH, Hamburg, Germany) while it was positioned over the abutment (Fig. 1). A rounded notch for the application of the centric loading was created manually in composite resin in the vertical axis of the tooth, for eccentric loading a standardized groove was present in the metal extension. So the threshold of tactile sensitivity could be examined on the freestanding abutment teeth without proximal contacts to adjacent teeth.

The threshold of tactile sensitivity was passively assessed using two force gauges (Correx Force Gauge 25–250 and 200–2000 cN, Correx, Hahn + Kolb Werkzeuge GmbH, Stuttgart, Germany). Pressing slowly down the feeler arm of the gauge with its rounded tip, a continuously increasing axial force up to 2000 cN was applied first centrically and then eccentrically parallel to the tooth axis. The reproducibility of manual force application was evaluated using a modified typodont in a universal testing machine (Zwick Z010; Zwick GmbH, Ulm, Germany). The measured force application varied between 2.4 and 4.3% for the 250 cN force gauge and between 2.2 and 2.7% for the 2000 cN force gauge when measurements were repeated 10 times.

The order of loading the teeth was randomized. Throughout the study, loading was applied blinded by the same individual, who thus did not know whether the loaded tooth was vital or endodontically treated. Every testing was videotaped for a precise subsequent analysis. While the loading force was increased continuously, the patient had

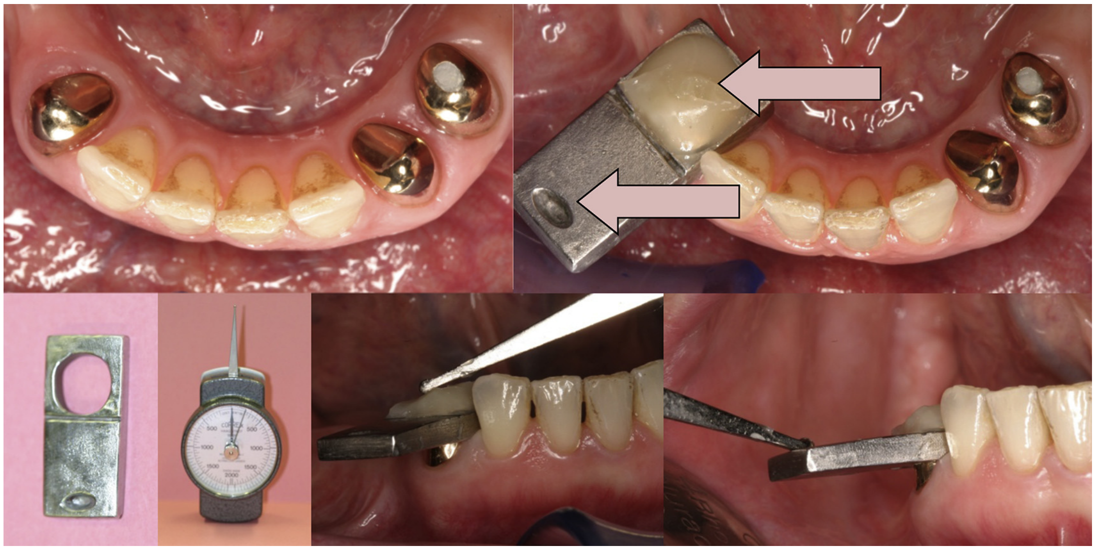

Fig. 1 – Experimental design. (A) Vital and non-vital canines with inner copings. (B) Individualized extension. Arrows are pointing to the metal groove and the composite resin notch as loading points for the tip of the feeler arm of the force gauge. (C) Metal extension. (D) Correx force gauge. (E) Applying centric loading axially with the rounded tip of the force gauge's feeler arm. (F) Applying eccentric loading parallel to the tooth axis.

been instructed to give acoustic signals with a beeper for both teeth for the following events:

(1) when noticing first contact—absolute threshold of perception,
(2) when noticing pressure, and
(3) when the pressure became displeasing.

Since data were not normally distributed, statistical analysis was performed by the Wilcoxon's signed rank and rank sum tests using SPSS, Version 17.0 with a level of significance of $\alpha = 5\%$. Unexpectedly, a large number of ties occurred, which reduces the value of the applied nonparametric statistical tests. For a sensitivity analysis of our results, we also analyzed the data with a log-rank test assuming that observations were independent and values above 2000 cN were regarded as censored. The power calculation of the study using BiAS for Windows, Version 8.03, revealed that with our sample size of 40 participants, a log-rank test with a significance level of 5% would be able to detect a difference of 30% in the tactile sensitivity between the groups with a power of more than 90%.

3. Results

The study group consisted of 24 male and 16 female participants with an average age of 68.2 years (min. 47.4—max. 88.3 years). The dental prostheses had been in function for an average time of 5.0 years (min. 0.5–max. 17.2 years). Twenty-one participants had maxillary teeth and 19 participants had mandibular teeth tested, respectively. The groupings for the subjects and teeth tested are anterior; 24 participants with 48 teeth (14 incisors and 34 canines), and posterior; 16 participants with 32 teeth (28 premolars and 4 molars). No abutment tooth fractured during testing.

The median values for the threshold of tactile sensitivity at centric and eccentric loading for vital teeth and ETT at three response levels did not differ significantly ($p > 0.05$) and are presented in Table 1 and Fig. 2. Eccentric loading provoked a displeasing feeling earlier than centric loading.

The response of vital teeth and ETT to loading varied greatly between individuals. A high subjectivity in detecting pressure or pain was apparent. No general reaction pattern of vital teeth and ETT to loading could be detected. Participant gender did not influence the tactile sensitivity of the loaded teeth, but women presented somewhat lower medians at all three response levels. The second statistical approach with the log rank test yielded similar results with no significant differences between groups ($p > 0.05$).

4. Discussion

To the best knowledge of the authors, this is the first clinical study comparing the tactile sensitivity of a larger number of

Table 1 – Median loading forces in cN for the three particular time points (1) when noticing the first contact, (2) when noticing pressure and (3) when the pressure became displeasing did not differ significantly between vital and non-vital teeth ($p > 0.05$).

		1	2	3
Centric loading	Vital	140	450	1800
	Non-vital	180	500	1500
Eccentric loading	Vital	150	400	1150
	Non-vital	125	450	1100

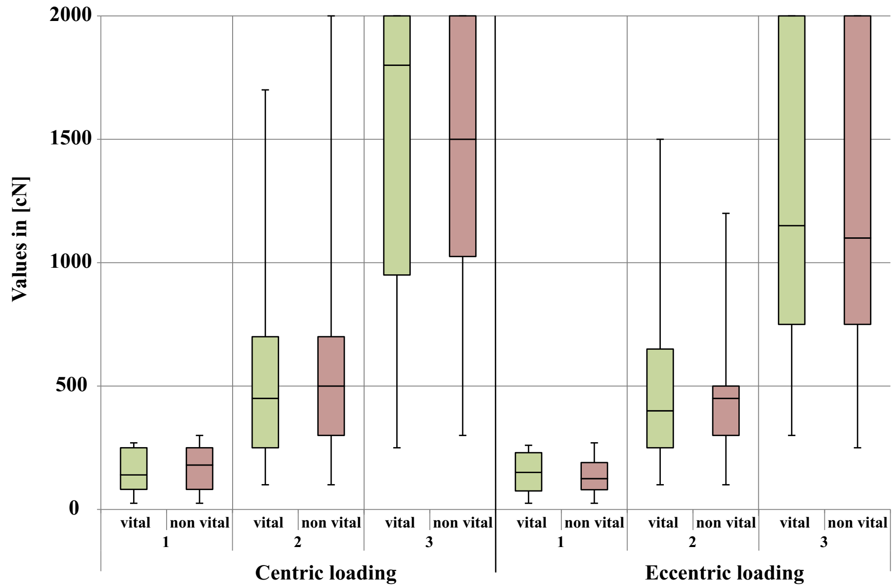

Fig. 2 – Loading forces in cN for the three particular time points. (1) When noticing the first contact, (2) when noticing pressure and (3) when the pressure became displeasing. No statistically significant differences between vital and non-vital teeth were found (*p* > 0.05). The boxplot depicts the distribution of recorded loading forces. The horizontal lines that intersect the colored boxes present the medians, the top of each box is the 75th percentile (Q3); the bottom is the 25th percentile (Q1) and horizontal lines above and below the boxes, called whiskers, represent maximum and minimum loading values. Values over 2000 cN were not evaluated for ethical reasons.

vital teeth and ETT serving as RPDP abutments. Proximal contacts with adjacent teeth were eliminated by the use of participants with double crown RPDPs. After removal of the RPDPs, the inner copings of the abutments could be loaded individually without any interference. Only one measurement per tooth in centric and eccentric position was performed to avoid the possibility of receptor adaption and a possible training effect of participants. In order to eliminate variations in sensitivity between individuals, only similar vital teeth and ETT of the same subject in the same jaw were compared. With the sample size of 40 participants, a difference of 30% in the tactile sensitivity of groups could be detected with a power of more than 90%, which was considered appropriate.

Neither load application (centric versus eccentric) nor gender of the participants influenced the tactile sensitivity of the tested teeth and no difference in tactile sensitivity between vital teeth and ETT could be detected. Therefore, the null hypothesis that the tactile sensitivity of ETT does not differ from vital teeth has to be approved.

These results are in contrast to an earlier study[9] in which a two-fold difference in the nociceptive responsiveness of ETT compared to vital teeth was reported. However, because of the rather low number of participants ($n = 3$) in that older study, an inadequate statistical power has to be assumed. Loewenstein and Rathkamp reported a 57% higher threshold for tactile perception for ETT than for vital teeth evaluating 10 individuals, but they did not evaluate when pressure was noticed or pressure became displeasing.[3] In the present study, the thresholds of tactile sensitivity of vital teeth and ETT were compared in 40 participants. A 22.3% higher threshold was found with ETT for the first sensation, which supports the findings of Loewenstein and Rathkamp. However, a 10% higher value for noticing pressure and a 20% lower value for displeasing pressure was calculated for ETT in the current study but these differences with no statistical significance for any level of perception.

In general, a loading of 1–10 cN is considered adequate to provoke the first sensation of teeth in a complete dentition with proximal contacts to the adjacent teeth.[3,7] In the current study when testing freestanding abutment teeth of RPDPs, we found much higher values for noticing the first contact with a median value of 140 cN for vital and 180 cN for non-vital teeth. A possible explanation for these differences might be a reduced discriminatory ability in elderly patients with removable dental prostheses.[4] It can be assumed that the higher loading forces on abutments of RPDPs will result in a neurologic adaptation to these day-to-day loading conditions during chewing with the RPDPs.

In general, the threshold values for vital teeth and ETT will be greatly influenced by the level of discriminatory ability in each individual. This was reflected in the substantial individual variety for noticing; the first contact (ranging from 25 to 250 cN), pressure (100–2000 cN) and displeasing pressure (250–2000 cN). Similar variations between individuals were reported in previous studies.[3,7] Forces higher than 2000 cN were not applied to the abutment teeth for ethical reasons as higher forces may damage the loaded teeth. Fortunately, no abutment tooth fractured during the measurements, which might be related to the low loading forces that were applied as compared to possible masticatory forces.[24–26] The latter might involve maximum forces of 300–500 N with a great individual variation.

Besides the amount of force, the loading direction seems to be important.[7,27] Forces directed on the surface of the restoration are transmitted to the supporting tooth structure. Fractures will occur at the weakest point or at the point of maximum stress.[28,29] Non-axial forces increase the risk for fatigue fractures. Horizontal loading, in particular, generates much higher levels of stress than vertical loading. Horizontal loading should be avoided[30,31] as it creates the greatest level of stress in the cervical region and at the post-dentin interface. The present study found lower threshold values for all sensations with eccentric loading but without a statistically significance.

In regard to gender, no significant differences in tactile sensitivity was detected, even though the females presented lower median values. It might be assumed that these results correlate to lower average masticatory forces of females.[32] This is supported by the literature where the mean threshold values regarding teeth were not significantly different between women and men. However, comparing teeth to implants, women had a significant finer discriminatory ability than men.[33]

There is a broad consensus in the literature that ETT are more susceptible to fracture than vital teeth.[8,10,16,18,19] However, our current results provide no evidence that the higher fracture risk of ETT would be caused by a reduced discriminatory ability in the periodontal ligament of ETT. Instead, we suggest that loss of tooth substance due to carious destruction and endodontic access cavity preparation is the major reason for the increased risk of fracture of ETT.[8,10,16,18,19] Furthermore, insertion of posts, instrumentation, irrigation and obturation during endodontic treatment introduce stresses to the tooth.[10–17]

5. Conclusions

The mean threshold values of freestanding vital teeth and non-vital teeth were not statistically significant. Thus, the tactile sensitivity seems comparable and the assumption that a lower threshold level for tactile sensitivity in non-vital teeth than in vital teeth is responsible for their increased fracture risk could not be confirmed. Therefore other reasons, e.g. a higher amount of substance loss, have to be considered to be responsible for the increased fracture risk of non-vital teeth.

Acknowledgments

The study was conducted and funded by departmental funding. The authors especially thank the dental assistant for her help during the study and Sönke Harder, Munich, for his input in the initial study design. In addition, the authors thank Ove A Peters, San Francisco University of the Pacific, and Van P Thompson, King's College London Dental Institute for their help in revising the original manuscript.

REFERENCES

1. van Steenberghe D. The structure and function of periodontal innervation. A review of the literature. *J Periodontal Res* 1979;**14**:185–203.
2. van Steenberghe D, de Vries JH. The development of a maximal clenching force between two antagonistic teeth. *J Periodontal Res* 1978;**13**:91–7.
3. Loewenstein WR, Rathkamp R. A study on the pressoreceptive sensibility of the tooth. *J Dent Res* 1955;**34**:287–94.
4. Christensen LV, Levin AC. Periodontal discriminatory ability in human subjects with natural dentitions, overlay dentures and complete dentures. *J Dent Assoc S Afr* 1976;**31**:339–42.
5. Storey AT. Sensory functions of the temporomandibular joint. *J Can Dent Assoc (Tor)* 1968;**34**:294–300.
6. Jacobs R, van Steenberghe D. Role of periodontal ligament receptors in the tactile function of teeth: a review. *J Periodontal Res* 1994;**29**:153–67.
7. Adler P. Sensibility of teeth to loads applied in different directions. *J Dent Res* 1947;**26**:279–89.
8. Wegner PK, Freitag S, Kern M. Survival rate of endodontically treated teeth with posts after prosthetic restoration. *J Endod* 2006;**32**:928–31.
9. Randow K, Glantz PO. On cantilever loading of vital and non-vital teeth. An experimental clinical study. *Acta Odontol Scand* 1986;**44**:271–7.
10. Al-Omiri MK, Mahmoud AA, Rayyan MR, Abu-Hammad O. Fracture resistance of teeth restored with post-retained restorations: an overview. *J Endod* 2010;**36**:1439–49.
11. Burke FJ. Tooth fracture in vivo and in vitro. *J Dent* 1992;**20**:131–9.
12. Fernandes AS, Dessai GS. Factors affecting the fracture resistance of post-core reconstructed teeth: a review. *Int J Prosthodont* 2001;**14**:355–63.
13. Lubisich EB, Hilton TJ, Ferracane J. Cracked teeth: a review of the literature. *J Esthet Restor Dent* 2010;**22**:158–67.
14. Lynch CD, Burke FM. Incomplete tooth fracture following root-canal treatment: a case report. *Int Endod J* 2002;**35**: 642–6.
15. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. *J Endod* 1989;**15**:512–6.
16. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. *J Endod* 2010;**36**:609–17.
17. Tikku AP, Chandra A, Bharti R. Are full cast crowns mandatory after endodontic treatment in posterior teeth? *J Conserv Dent* 2011;**13**:246–8.
18. Bitter K, Meyer-Lueckel H, Fotiadis N, Blunck U, Neumann K, Kielbassa AM, *et al.* Influence of endodontic treatment, post insertion, and ceramic restoration on the fracture resistance of maxillary premolars. *Int Endod J* 2010;**43**:469–77.
19. Hannig C, Westphal C, Becker K, Attin T. Fracture resistance of endodontically treated maxillary premolars restored with CAD/CAM ceramic inlays. *J Prosthet Dent* 2005;**94**:342–9.
20. Gher Jr ME, Dunlap RM, Anderson MH, Kuhl LV. Clinical survey of fractured teeth. *J Am Dent Assoc* 1987;**114**:174–7.
21. Lewinstein I, Grajower R. Root dentin hardness of endodontically treated teeth. *J Endod* 1981;**7**:421–2.
22. Testori T, Badino M, Castagnola M. Vertical root fractures in endodontically treated teeth—a clinical survey of 36 cases. *J Endod* 1993;**19**:87–90.
23. Mühlemann HR. Physiologic and pathologic dental mobility. *Schweizerische Monatsschrift fur Zahnheilkunde* 1951;**61**:1–71.
24. Bates JF, Stafford GD, Harrison A. Masticatory function–a review of the literature. 1. The form of the masticatory cycle. *J Oral Rehabil* 1975;**2**:281–301.
25. Carlsson GE. Bite force and chewing efficiency. *Front Oral Physiol* 1974;**1**:265–92.
26. Helkimo E, Ingervall B. Bite force and functional state of the masticatory system in young men. *Swed Dent J* 1978;**2**:167–75.

27. Mericske-Stern R, Hofmann J, Wedig A, Geering AH. In vivo measurements of maximal occlusal force and minimal pressure threshold on overdentures supported by implants or natural roots: a comparative study, Part 1. *Int J Oral Maxillofac Implants* 1993;**8**:641–9.
28. Torbjorner A, Fransson B. A literature review on the prosthetic treatment of structurally compromised teeth. *Int J Prosthodont* 2004;**17**:369–76.
29. Himmel R, Pilo R, Assif D, Aviv I. The cantilever fixed partial denture—a literature review. *J Prosthet Dent* 1992;**67**:484–7.
30. Al-Omiri MK, Rayyan MR, Abu-Hammad O. Stress analysis of endodontically treated teeth restored with post-retained crowns: a finite element analysis study. *J Am Dent Assoc* 2011;**142**:289–300.
31. Liao R, Zhao Y. Stress analysis of prosthodontics by finite element method. *Sheng Wu Yi Xue Gong Cheng Xue Za Zhi* 2011;**27**:1415–9.
32. Haraldson T, Carlsson GE. Bite force and oral function in patients with osseointegrated oral implants. *Scand J Dent Res* 1977;**85**:200–8.
33. Hämmerle CH, Wagner D, Brägger U, Lussi A, Karayiannis A, Joss A, *et al*. Threshold of tactile sensitivity perceived with dental endosseous implants and natural teeth. *Clin Oral Implants Res* 1995;**6**:83–90.