

SHORT COMMUNICATION

In-vitro simulation of tooth mobility for static and dynamic load tests: A pilot studyGUIDO STERZENBACH¹, SVEN KALBERLAH¹, FLORIAN BEUER²,
ROLAND FRANKENBERGER³ & MICHAEL NAUMANN⁴

¹Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders, Charité - Universitätsmedizin Berlin, Berlin, Germany, ²Department of Prosthetic Dentistry, University clinic Munich, Munich, Germany, ³Department of Operative Dentistry and Endodontology, University of Marburg, Marburg, Germany, and ⁴Department of Prosthetic Dentistry, University of Ulm, Ulm, Germany

Abstract

Objective. Simulation of tooth mobility *in vitro* with or without reduced bone support is an aspect of particular interest from the clinical perspective. To elucidate adequate simulation of the periodontal ligament in terms of tooth mobility, three materials were investigated. **Methods.** Human lower sound premolars were selected and randomly assigned to six groups ($n = 5$) and stored at 37°C in a 0.5%-chloramine solution. For tooth mobility simulation, roots were covered with a thin layer of three types of material: (i) polyurethane elastomeric material, (ii) polyether impression material and (iii) A-polysiloxane soft cushion material. Teeth were embedded in an acrylic resin block simulating no and 50% bone loss, respectively. Specimens were statically subjected up to a maximum load of 30 N perpendicular to tooth axis (crosshead speed = 1 mm/min) in a universal material testing machine. Load-deflexion curves and periotest values were recorded. Statistical analysis was performed using 2-way Anova and post-hoc Bonferroni Test ($p = 0.05$). The Pearson's correlation coefficient between deflexion and periotest values was calculated. **Results.** Median horizontal deflexion values (μm) of specimen crowns with no bone loss were significant higher for polysiloxane (210) compared to polyurethan (24) ($p < 0.001$). The tooth deflexion, e.g. tooth mobility, increased significantly as the bone level decreased only when specimens were embedded in polysiloxane (iii) (1150) ($p = 0.045$). All specimens with reduced bone support layered with polyether were dislocated. Deflexion was significantly positive correlated with periotest values ($p = 0.01$). **Conclusion.** Using A-polysiloxane soft cushion material combined with autopolymerizing acrylic resin may be suitable to simulate increased tooth mobility *in vitro*.

Key Words: *Chewing simulation, thermomechanical loading, thermocycling and mechanical loading*

Introduction

Compared to clinical studies, *in-vitro* studies are less time consuming and inexpensive. However, as discussed elsewhere [1], specifically for testing of post-endodontic restorations, *in vitro* study set-up shows a great variety. It is very likely that this would have an impact on study results and, thus, on conclusions drawn. One basic aspect of *in-vitro* testing is the type of embedment of natural teeth as specimens and in particular periodontal ligament simulation in terms of tooth mobility. Physiological tooth movement depends on the viscoelastic behavior of the periodontal ligament (PDL). The PDL consist of

collagen fibers embedded in non-collagenous glycoproteins and proteoglycans that attach the tooth cementum to the alveolar bone. Additionally, blood vessels, lymphatics and nerves are part of the PDL. Due to this complex biological tissue the force response of the tooth is non-linear anisotropic, time-dependent and sensitive to strain rate and strength [2].

To date only little information can be found on how to simulate tooth mobility for *in-vitro* fracture load testing close to a clinical situation. Soares et al. [3] compared different approaches to study the impact of root embedment material on fracture resistance. It was shown that embedment of bovine teeth and

embedding materials do have an impact on fracture resistance and modify fracture modes.

An *in-vitro* study using thermal cycling and mechanical loading (TCML, 1.2×10^6 load cycles 1–49 N, thermo cycles 5–55°C) with subsequent linear compressive loading until failure found that reduction of the alveolar bone support reduces maximum load capability of post-endodontic restorations [4]. Other investigators [5] describe in a FEA that under simulated bite force the tensile stress increased at the lingual cervical region of upper central incisors when alveolar bone support decreases. It was suggested that alveolar bone height reduction potentially causes mechanical damage to the periodontal ligament. Recently it was shown that as tooth mobility increases (due to reduced alveolar bone support), tensile stresses increase in prosthetic restorations [6]. Thus, tensile stress may be a crucial factor for longevity, in particular for all-ceramic fixed partial dentures. It can be concluded that embedding materials used to simulated tooth mobility and simulated bone support should be given more attention when teeth are used as specimens for *in-vitro* studies. However, to date no approach was described which simulate tooth mobility *in vitro* as found clinically. Hence, to the best of our knowledge for the first time a study was conducted in order to validate tooth mobility simulation. Two commonly used [1] and one new specimens embedding approaches were investigated when alveolar bone support was complete and reduced by 50%.

The working hypothesis tested was that the new approach is appropriate to simulate tooth mobility as it can be observed clinically.

Materials and methods

Human lower sound premolars were selected and randomly assigned to six groups ($n = 5$) and stored at 7°C in a 0.5%-chloramine solution. In a first step, roots were coated with a thin layer of wax (0.3 mm casting wax veined green, Dentaurem, Pforzheim, Germany) and blocked out 2.5 mm (wax wire round, Dentaurem, Pforzheim, Germany) below the cemento-enamel junction (CEJ), simulating biological width. To simulate 50% bone loss the roots were coated up to half of the root length (distance between CEJ and apex). In a second step, teeth were mounted in a standardized manner in an acrylic resin block (Technovit 4004, Heraeus Kulzer, Germany). After polymerization, roots were removed and cleaned. To simulate the tooth mobility the roots were covered in group (i) with polyurethane elastomeric material (Anti-Rutschlack, Kaddi-Lack, Germany) and in group (ii) with polyether impression material (ImpregumTM PentaTM, 3M Espe, Seefeld, Germany). Both materials were described for *in-vitro* load-to-fracture studies [7–9] and served as

control. Respective materials were placed into the simulated socket and the teeth were relocated. In group (iii) an A-polysiloxane soft cushion material combined with autopolymerizing acrylic resin was tested. Specimens of group (iii) were coated with a thin layer of autopolymerizing acrylic resin (Paladur[®], Heraeus Kulzer, Germany). After polymerization the adhesive was applied. The soft cushion material (Mollosil[®], DETAX, Germany) was placed into the simulated socket and specimens were relocated in a standardized manner.

Now tooth mobility was measured three times for each specimen by means of a periostest device perpendicular to tooth axis (PERIOTEST Classic, Medizintechnik Gulden, Germany). One out of at least two equal periostest values were taken for further analysis. All specimens were subjected to static linear loading up to a maximum load of 30 N perpendicular (90°) and parallel (0°) to the tooth axis at a crosshead speed = 1 mm/min in a universal material testing machine (Z 005/TN2A, Zwick, Germany). The load-deflexion curves and the maximum deflexion at 30 N were recorded (resolution of extensometer: $0.06 \mu\text{m} \pm 0.15\%$) Statistical analysis was performed using 2-way Anova and post-hoc Bonferroni Test. The Pearson's correlation coefficient between the deflexion and the periostest values was calculated. All test were two-sided ($\alpha = 5\%$).

Results

The mean deflexion values (μm) of the premolar crowns of axial loading were significantly different between the groups of embedding material ($p < 0.001$), but independent of bone loss. The tooth deflexion at maximum load was significantly higher for polyether (ii) and polysiloxane (iii) then polyurethan (i) ($p = 0.005$; $p = 0.001$) (Table I).

Under perpendicular loading the deflexion is dependent on the embedding material ($p < 0.001$), bone loss ($p < 0.001$) and the combination of both variables

Table I. Tooth deflexion at axial loading (0° to tooth axis) at maximum load of 30 N.

Group	Bone level* (%)	deflexion* mean (μm)	Standard deviation (μm)
(i) polyurethan	100	10 ^a	0
(i) polyurethan	50	14 ^a	5
(ii) polyether	100	66 ^b	48
(ii) polyether	50	39 ^b	7
(iii) polysiloxane	100	70 ^b	34
(iii) polysiloxane	50	52 ^b	18

*bone level: 100% = 2.5 mm below CEJ; 50% = distance CEJ to apex/2.

Equal letters indicate no significant difference at $p > 0.05$, different letters indicate significant differences at $p \leq 0.005$.

Table II. Tooth deflexion at perpendicular loading (90° to tooth axis) at maximum load of 30 N.

Group	Bone level* (%)	deflexion*mean (µm)	Standard deviation (µm)	Periotest value (range)
(i) polyurethan	100	24 ^a	5	-5-3
(i) polyurethan	50	32 ^a	13	-2-4
(ii) polyether	100	246 ^b	148	-1-5
(ii) polyether	50	all roots dislodged from mould		
(iii) polysiloxane	100	210 ^b	176	+3-15
(iii) polysiloxane	50	1150 ^c	476	+25-38

*bone level: 100% = 2.5 mm below CEJ; 50% = distance CEJ to apex/2.

Different letters indicate significant difference at $p \leq 0.001$; correlation of tooth mobility and Periotest values according to manufacturers' instructions (Medizintechnik Gulden e.K., Modautal, Germany): 0 = -08 to + 09; I = +10-19; II = +20-29; III = + 30-50.

($p < 0.001$). The deflexion values were significantly higher for group (iii) compared to (i) ($p < 0.001$) (Table II). For 50% bone loss a significantly higher tooth deflexion was found for specimens of group (iii) than for group (i) ($p < 0.001$). All specimens with reduced bone support layered with polyether (ii) were dislocated out of the mould and therefore excluded from further statistical analysis. The horizontal tooth deflexion, e.g. tooth mobility, increased significantly as the bone level decreased only when specimens were embedded in polysiloxane (iii).

The measured deflexion correlated significantly with periotest values ($p = 0.01$) (Figure 1).

Discussion

Neither polyurethane elastomeric material nor polyether impression material are as suitable as the newly described approach to combine an A-polysiloxane soft

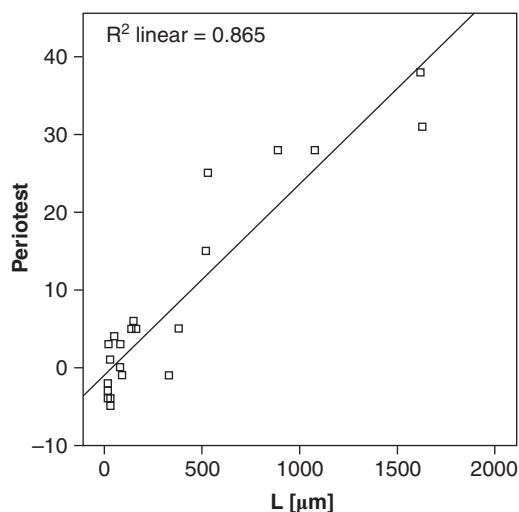


Figure 1. Scatter plot including best straight line of Periotest values by tooth deflexion (µm); R^2 = coefficient of determination.

cushion material with autopolymerizing acrylic resin. The tooth mobility values measured for teeth without alveolar bone loss are similar to that originally described by Mühlemann [10] clinically. The values of axial and horizontal tooth displacement are comparable to that found by Ona and Wakabayashi [5] in their mathematical models. Despite differences in load direction (45°), tooth type (maxillary incisor) and applied load (14.5 N) the horizontal tooth deflexion was comparable for normal and reduced alveolar bone support. Since an impact on fracture load and fracture patterns under normal alveolar bone support simulation and mechanical damage under reduced bone support may be likely, the combination of A-polysiloxane soft cushion material combined with autopolymerizing acrylic resin should be considered in future for *in-vitro* tests. The working hypothesis was confirmed.

Conclusion

It appears that A-polysiloxane soft cushion material combined with autopolymerizing acrylic resin is particularly suitable to simulate increased tooth mobility *in vitro*.

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

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