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Reference


DOI : 10.1111/j.1600-0501.2011.02283.x
PMID : 22092337
Mechanosensation and maximum bite force in edentulous patients rehabilitated with bimaxillary implant-supported fixed dental prostheses

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Key words: active threshold sensitivity, implant-supported fixed dental prostheses, maximum voluntary bite force, mechanosensation, passive threshold sensitivity, tactile sensitivity

Abstract
Objective: The aim of this study was to compare tactile sensitivity and maximum voluntary bite force (MBF) of edentulous patients with implant-supported fixed dental prostheses (IFDP/IFDPs) to those wearing complete dentures (CG-CC) and fully dentate subjects (CG-DD).

Methods: Seven edentulous subjects with IFDP/IFDPs, seven with CG-CC and seven CG-DD, matched for age and gender, participated in the pilot experiments. Three active tactile thresholds (absolute, 50% and 100%) were evaluated by means of copper foils of decreasing thickness (12 foils: 700–5 µm). The passive thresholds were measured in six different sites per quadrant using a custom-made computer-supported strain gauge. MBF was evaluated electronically using the central-bearing point method.

Results: Active tactile thresholds were different between all three groups of dental state (Kruskal–Wallis: absolute P = 0.0156; 50% P = 0.0019; 100% P = 0.0059). The active tactile sensitivity with IFDP/IFDPs was between those of the two other groups, except for the 100% threshold. The median passive tactile threshold was higher in patients with IFDP/IFDPs (5.7 N) than in CG-CC (1.7 N) and CG-DD (0.5 N) (Kruskal–Wallis P < 0.0005). MBF did not differ significantly between the dental states (ns).

Conclusion: IFDP/IFDPs are a valuable treatment option for restoring edentulous patients. Limitations concerning their physiological integration into the orofacial system are mainly related to a poor passive rather than active tactile sensitivity or maximum bite force.

“Now I understand why you made such an effort to keep my last tooth, with the new dentures I don’t feel a lot between the teeth.”

Reported one of our patients following the extraction of his last canine and providing him with an implant-supported overdenture.

Complete tooth loss results in atrophy and subsequent decrease of periodontal receptors. Moreover, a diminution ofafferent nerve fibres in the mandibular canal was also demonstrated in an animal model (Linden & Scott 1989). The periodontal ligament hosts mechanoreceptors which transmit tactile stimuli to the central nervous system (Linden 1990, Berkovitz et al. 1995). These receptors are sensitive to load and allow for the adaptation of centrally generated biting and chewing patterns (Schindler & Hugger 2006) by providing afferent information on magnitude, direction and rate of occlusal load.

Receptor function can be examined by neurophysiological as well as psychophysical methods. Neurophysiological tests are used scarcely because they are invasive and require a skilled performance [Trulsson et al. 1992]. Sensory function can also be evaluated by psychophysical testing, relying on the patient’s response. If realized in a standardized manner, this method allows correlating the patient’s perception with the physiological receptor functions. Different approaches have been described for assessing of the threshold of oral tactile sensitivity; first, the determination of the active threshold which evaluates the interocclusal detection of small objects and second, the passive threshold which is determined by applying a mechanical stimulus without vibration to the clinical crown of a tooth [Jacobs et al. 2002].

Oral implants are widely used to restore oral function after tooth loss [Thomason
variable than in dentate subjects. This was observed in patients with conventional full dentures as well as in patients with implant-supported overdentures (Trulsson & Gunne 1998). Furthermore, in implant-supported bridge wearers, the muscle activity during chewing is less adapted to the softening of the food bolus in than dentate individuals (Haraldson 1983). Concerning the maximum bite force, it is well known that complete denture wearers exert much lower bite forces than subjects with a natural dentition or fixed implant-supported dental prostheses (Haraldson et al. 1979, Müller et al. 2011).

The aim of this study was to test the following hypotheses:

- Edentulous patients restored with full-mouth IFDP/IFDP compared with fully dentate subjects (CG-DD) have a reduced active and passive sensitivity, but perform still better than conventional complete denture wearers (CG-CC).
- Patients with IFDP/IFDP exert a higher maximum voluntary bite force (MBF) than CG-DD and CG-CC.

Material and methods

The study was approved by the ethics committees of the University Hospitals of Geneva, Switzerland (07-166/Psy 07-025). Written informed consent was obtained.

Participants

Participants were recruited from patients and staff of the Geneva Dental School. Inclusion criteria for the experimental group comprised being edentulous and wearing IFDP/IFDP for at least 6 months prior to the experiments. Exclusion criteria were a history of neurological impact of implant-supported overdentures (Lundqvist & Haraldson 1984; Jacobs & van Steenberghe 1991; Enkling et al. 2009). However, physiological and neurological impact of implant-supported tooth replacement is still not fully understood (Klineberg et al. 2005). The active tactile sensitivity of a single-tooth implant was reported either similar to natural teeth or reduced (Lundqvist & Haraldson 1984; Jacobs & van Steenberghe 1991; Enkling et al. 2007). Methodological differences between the studies may account for these differences. The integration of the single-tooth implant with regard to tactile perception might be explained by the stimulation of the periodontal structures of the natural antagonist or the adjacent natural tooth. But even when all teeth are lost, there is a sensitivity directly related to bone-anchored implants, which was termed osseoperception, yet the origins of these sensations are still under discussion (Klineberg et al. 2005). The active tactile threshold in implant-supported overdenture wearers is 3–5 times higher than dentate volunteers, but about twice as good as in complete denture wearers (Utz 1986; Jacobs & van Steenberghe 1991; Lobbezoo et al. 2002). Yet overdentures on natural roots allow for an even more precise detection of inter-occlusal foreign bodies than implant-supported overdentures (Mericsek-Stern 1994). Full-mouth implant-supported fixed dental prostheses (IFDP/IFDPs) have scarcely been investigated concerning their neuro-physiological integration, yet a better active tactile sensitivity than in conventional complete denture wearers was reported in a sample of eight subjects (Batista et al. 2008).

Already in the very early dental literature, the passive tactile thresholds of natural teeth has been reported within the range of 0.01–0.1 N (Manly et al. 1952). Implant-supported single crowns are significantly less sensitive to tactile stimuli (Grieznis et al. 2010). Hämmerle et al. (1995) found that the passive tactile threshold of perception was 8.75 times higher in single implant crowns. Mericske-Stern et al. (1993) reported a 100-fold passive tactile threshold in patients with conventional upper and implant-supported lower overdenture wearers compared with overdenture on natural roots. The threshold to passive tactile stimuli of patients with IFDP/IFDP restorations was reported within the range of implant-supported overdentures, yet with a larger inter-individual variation (Jacobs & van Steenberghe 1993).

The lack of periodontal receptors seems to also affect the fine tuning of mandibular movement (Lobbezoo et al. 2002). In edentulous patients, forces used during hold and split tasks are considerably higher and more...
were used: 700, 500, 250, 150, 125, 100, 75, 50, 30, 20, 10 and 5 μm (Fig. 1). Per thickness level, 10 trials were performed and further five mock experiments where no foil was presented. The mock trials occurred in randomized order (http://www.randomizer.org). Tactile sensibility was expressed as percentage of correctly detected foils (Tryde et al. 1962).

Three different thresholds were defined:

[1] The 100% threshold describes the thinnest thickness level at which all presented foils and mock trials were identified correctly.

[2] The 50% threshold describes the thickness level where the number of correctly detected foils minus the incorrectly identified mock trials is 5. If this occurred for several thickness levels, the median value was calculated.

[3] The absolute threshold describes the thinnest foil which could be detected.

Furthermore, the range within the 10% and 90% threshold levels gave an estimation of the “certainty” and “precision” of the detection of the interocclusal foil (Enkling et al. 2010a, 2010b).

Passive tactile threshold

The passive tactile threshold represents the smallest mechanical load to the teeth detected by the patient. For this test, the patient was comfortably seated on a padded armchair with the head reclined against the wall. A computer-assisted custom-made strain-gauge measuring device was calibrated with standardized weights. It consisted of a bendable bi-metal spatula which was linked to an A/D converter (CED 1401®, Cambridge, UK). The signal was amplified, A/D converted and stored for off-line analysis using the Spike2® software (CED). The tip of the gauge was covered with polyether impression material (Impregum®, ESPE, Seefeld, Germany). The participants were asked to indicate the first mechanical sensation by pressing a button which was simultaneously registered by the A/D converter. To avoid vibrations during the measurements, the operator’s arm rested on a support. The gauge was placed on the tooth surface and the force was increased continuously until the patient pushed the marker button. Force applications were limited to 8 N.

The passive threshold was tested in all four quadrants on four different teeth. Load was applied on the occlusal and vestibular surface on molars and premolars, on canines and incisors, the load was applied only on the vestibular surface (six surfaces per quadrant). Quadrants were tested from one to four, the testing sequence within each quadrant was randomized. Each surface was tested three times and the measurements were averaged for further analysis. The total passive thresholds were expressed as mean of median from all six measured sites in all four quadrants of the median of three measurements per site.

Maximum voluntary bite force

Maximum central bite force was measured using a strain gauge with Type 6/120 MY 21 (custom made by Prof. R. Ott, University of Erlangen, Germany) with confirmed linearity from 1 to 1000 N (Hardtmann et al. 1989). Registration plates were fabricated individually on plaster casts which were poured from alginate impressions (Fig. 2a and c). Measurements were taken according to the central-bearing point method which distributes the force evenly to all supporting tissues (Fig. 2b). The gauge was attached with a thermoplastic material (Kerr Ltd, Peterborough, UK) to the registration plates. The gape was kept as small as possible. The force gauge was connected via a 1401+® AD converter (CED) to a standard PC. The signal was recorded, stored and analysed off-line with the Spike2® software (CED).
Statistical analysis

Variance of data was tested using F-tests. Consequently, continuous data were compared using Kruskal–Wallis tests to detect differences between groups of different dental states. Post hoc tests for differences between pairs were calculated using non-parametric Mann–Whitney tests for unpaired samples and Bonferroni correction was applied. Repeated measures within groups were compared using Friedman tests. Paired data were tested using Wilcoxon signed rank test. The level of significance for type 1 errors was set at $\alpha < 0.05$. Hypothetical sample size calculation for MBF was performed for type 2 errors with a power of $1 - \beta > 0.8$ using G*Power 3.1.2 [Franz Faul, University of Kiel, Germany]. Normal distribution was not assumed due to the small sample size. Statistical analysis was performed with StatView for Windows V5.0 (SAS Institute, Cary, NC, USA).

Results

Active tactile thresholds

In all three groups, the absolute threshold was smaller than the 50% and 100% threshold ($P < 0.01$, Friedman) (Table 2). There were significant differences [Kruskal–Wallis] between the three groups of different dental state [IFDP/IFDP, CG-CC, CG-DD] for the absolute threshold ($P = 0.0156$), the 50% threshold ($P = 0.0019$) as well as for the 100% threshold ($P = 0.0059$). The highest absolute and 50% thresholds were found in CG-CC, followed by IFDP/IFDP and CG-DD (Fig. 3). However, these differences were significant only for the 50% thresholds ($P < 0.05$, Mann–Whitney). If applying Bonferroni correction for multiple measurements, the p-level for significance is $P < 0.0167$ and only the 100% thresholds between IFDP/IFDP and the two control groups remain significant. For the absolute, 50% and 100% active tactile thresholds, the variance of the results was significantly different between groups [all $P < 0.01$, F-test], except for the 100% thresholds in IFDP/IFDP and CG-CC [ns, F-test]. One IFDP/IFDP participant’s absolute and 50% thresholds were at 700 $\mu$m.

The 100% threshold level of two patients from the IFDP/IFDP group was even above the highest tested thickness level of 700 $\mu$m, but the difference to CG-CC was not significant [ns, Mann–Whitney]. In the complete denture group, only one participant showed a threshold beyond the test range. Both groups, IFDP/IFDP and CG-CC, showed significantly higher 100% thresholds than CG-DD ($P = 0.0015$ and $P = 0.0199$, respectively; Mann–Whitney).

The support area, meaning the range between the 10% and 90% threshold was in dentate subjects between 0 and 20 $\mu$m, in the complete denture wearers between 10 and 250 $\mu$m and for the experimental group between 0 and 700 $\mu$m.

Passive tactile threshold

The passive tactile threshold was significantly different between the three different test groups for all measured sites (0.0003 $< P < 0.0002$, Kruskal–Wallis). Furthermore, the variance between groups was significantly different [all $P < 0.05$, F-test], except between CG-CC and CG-DD for the occlusal load on premolars and the vestibular load on incisors ($P = 0.0537$ and $P = 0.0749$, respectively; F-test) (Fig. 4). Highest passive thresholds were found in the IFDP/IFDP group, in which two patients showed a passive tactile sensitivity above the range of the used measuring device ($x > 8$ N). These passive thresholds remained significantly higher after Bonferroni correction. There was no significant difference between left and right side or upper and lower arches in each of the groups (all ns, Mann–Whitney).

In IFDP/IFDP, no consistent difference of passive tactile thresholds between incisors, premolars and molars was found [ns, Wilcoxon]. However, there was a significant difference between the passive threshold of the incisors and the occlusal passive threshold of the molar and premolar teeth in CG-DD ($P = 0.0425$ and $P = 0.0280$, respectively; Wilcoxon). Furthermore, passive tactile thresholds in CG-CC were different between incisors and occlusal load of the premolars ($P = 0.0425$, Wilcoxon). In all three groups, no significant differences were found between the passive tactile threshold in premolars and molars when the stimulus was presented either on the occlusal or the vestibular surface of the tooth or the prostheses [ns, Wilcoxon].

The mean passive tactile threshold [mean of median from all six measured sites in all four quadrants of the median of three measurements per site] of all evaluated sites was in IFDP/IFDP ($5.65 \pm 1.15$ N) 3.5 times higher than in CG-CC ($1.71 \pm 0.23$ N) and 12.5 times higher than in CG-DD ($0.46 \pm 0.07$ N) [$P = 0.0005$, Kruskal–Wallis].

![Fig. 3. Box-plot of the absolute, 50% and 100% active tactile thresholds in edentulous participants with conventional full dentures (CG-CC, n = 7) or bimaxillary implant-supported fixed dental prostheses (IFDP/IFDP, n = 7) as well as in a fully dentate control-group (CG-DD, n = 7) [P-values: Kruskal–Wallis, *Mann–Whitney P < 0.05].](image)

![Fig. 4. Box-plot of the passive tactile thresholds, the median values of all four quadrants are displayed. They were calculated from six measurements per quadrant: M, molar, Pm, premolar, C, canine, I, incisor, o, force applied on occlusal surface, v, force applied from vestibular surface. The passive tactile threshold was significantly different between the three different groups for all measured sites (0.0003 $< P < 0.0002$, Kruskal–Wallis).](image)

### Table 2. Active tactile thresholds (μm)

<table>
<thead>
<tr>
<th>Threshold level</th>
<th>Group</th>
<th>Median</th>
<th>Mean*</th>
<th>SD*</th>
<th>Minimum</th>
<th>Maximum</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td>CG-CC</td>
<td>30</td>
<td>46.4</td>
<td>46.4</td>
<td>10</td>
<td>125</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IFDP/IFDP</td>
<td>10</td>
<td>115</td>
<td>258.5</td>
<td>&lt;5</td>
<td>700</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CG-DD</td>
<td>5</td>
<td>5.7</td>
<td>1.9</td>
<td>&lt;5</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>50%</td>
<td>CG-CC</td>
<td>119.6</td>
<td>62.9</td>
<td>25</td>
<td>200</td>
<td>250</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IFDP/IFDP</td>
<td>20</td>
<td>123</td>
<td>255.9</td>
<td>7.5</td>
<td>700</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CG-DD</td>
<td>7.5</td>
<td>7.9</td>
<td>4.7</td>
<td>&lt;5</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>100%</td>
<td>CG-CC</td>
<td>450</td>
<td>244.9</td>
<td>150</td>
<td>&gt;700</td>
<td>&gt;700</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IFDP/IFDP</td>
<td>425</td>
<td>328.2</td>
<td>75</td>
<td>&gt;700</td>
<td>&gt;700</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CG-DD</td>
<td>72.9</td>
<td>52.5</td>
<td>20</td>
<td>125</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

CG-CC, complete denture wearers; IFDP/IFDP, implant-supported fixed dental prostheses; CG-DD, fully dentate subjects.

*Values above 700 μm are calculated with 800 μm, values below 5 μm with 0 μm.
Maximum voluntary bite force

Maximum voluntary bite force, as evaluated according to the central-bearing point principle, did not show any significant differences between the three dental states despite a trend to higher MBF in dentate participants (Kruskal-Wallis, Mann-Whitney) (Table 3).

Using the current method for measuring MBF, in each group CG-CC and CG-DD a sample size of \( n = 21 \) would have been necessary to demonstrate a significant difference with a power of 80% between groups. In each group, CG-DD and IFDP IFDP a sample size of \( n = 20 \) needed to be included to achieve a significant difference. To demonstrate a significant difference between CG-CC and IFDP IFDP with such a power of the statistical test, \( n = 484 \) participants would have to be recruited in each group (total \( n = 968 \)).

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG-CC</td>
<td>122.9</td>
<td>135.8</td>
<td>50.3</td>
<td>55.4</td>
<td>208.6</td>
<td>7</td>
</tr>
<tr>
<td>IFDP IFDP</td>
<td>137.5</td>
<td>125.5</td>
<td>75.9</td>
<td>36.4</td>
<td>252.2</td>
<td>7</td>
</tr>
<tr>
<td>CG-DD</td>
<td>180.4</td>
<td>194.6</td>
<td>91.8</td>
<td>95.3</td>
<td>378.8</td>
<td>7</td>
</tr>
</tbody>
</table>

Differences between three groups were not significant (ns, Kruskal-Wallis).

Critique of the method

Critique of the method arises from the psychophysical testing method. Any information obtained on the tactile sensitivity is indicated by the patient himself, thus no “objective” neurophysiological activity of the receptors was derived (Jacobs 1998).

Parameters like attention, fatigue, distraction and motivation have certainly influenced the psychophysically measured tactile thresholds. A possible age-related retardation of the receptors was derived (Jacobs 1998). No “objective” neurophysiological activity of the patients was detected by the copper foils, they were asked to “close down,” but this could be interpreted differently from one person to another. The use of the foils in descending order might have embellished the results of the active threshold level, but was chosen to allow comparison to other studies from the literature. To keep the measurements as objective as possible, white noise was used to avoid bone conduction (Utz 1986). Last but not least, randomization of the testing sequence aimed to avoid bias.

Interpretation of results

The results of this study revealed significant differences in tactile sensitivity between the test groups. The active threshold of participants with IFDP IFDP was between those of the CG-CC and the CG-DD control groups for the absolute and 50% thresholds. However, the 100% thresholds with IFDP IFDP showed a similar median active threshold to CG-CC, possibly caused by the large variability between individuals and the small sample size. However, the 50% thresholds which are considered a robust measure with clinical relevance are in agreement with reports in the literature (Batista et al. 2008). IFDP IFDP wearers presented the largest support area, indicating a lower certainty to detect an interocclusal foil or not in comparison with both control groups. This confirms findings from Enkling et al. (2010b) who reported that subject with natural teeth present with a smaller support area than those with implants.

With the extraction of teeth, the periodontal tissues are removed to a large extent. The few periodontal receptors which remain in the socket disappear when no longer stimulated by mechanical loading. Consequently, one could assume that the tactile sensitivity in complete denture wearers is not present any more. Clinical studies, however, show that other receptors of the orofacial system take over the detection of mechanical stimuli and it is assumed that mucosal and periostial receptors are largely involved. Other afferents may arise from the muscle spindles, the Golgi-tendon organs or the receptors located in the ligaments of the temporo-mandibular joint. In the literature, the active tactile thresholds of complete denture wearers have been reported to be 7–9 times higher than the one of dentate subjects. Despite the small sample size of the CG-CC, data from the present experiments are within the range reported in the literature (Utz 1986; Greewen 1987; Müller et al. 1995; Müller 2006).

Only few remaining natural roots maintain the tactile sensitivity substantially, as shown for patients wearing overdentures with implants vs. natural roots. Mericske-Stern reported on similar 50% thresholds, but a significantly lower threshold for the detection of the minimal interposed thickness in implant overdentures. Hence, the active tactile sensitivity appears to be largely enhanced by the presence of periodontal receptors (Mericske-Stern 1994).

Implants have no periodontal ligament, nevertheless, patients with implant-supported prostheses still show some awareness of mechanical stimuli applied to the implants. A consensus conference in 2005 suggested two distinctly different mechanisms for osseoperception: (a) receptors are located in the direct surrounding of the implant, for example, residual periodontal receptors and (b) mechanical stimuli are received by distant receptors, for example, adjacent natural teeth or skin, mucosa, periosteum, muscles tendons or joints (Klineberg et al. 2005).

Although small nerve fibres were found in the bone marrow and the periosteum, their contribution to mechanical stimuli remains unclear. Animal experiments showed nerve fibres in direct relation to dental implants but with time, their number seems to decrease (Linden & Scott 1989). It is therefore assumed that these were residual periodontal structures which no longer served a physiological purpose and thus disappeared. A further theory on osseoperception states that mandibular deformation was sensed by the receptors of periosteum and mucosa. It is also being discussed whether the muscle spindles, which are known to be very sensitive to vibration, play a role in osseoperception (Klineberg et al. 2005). This theory is supported by studies which report that the application of local anaesthesia to the implant or the antagonistic tooth does not significantly alter the active tactile sensitivity of implants (Lundqvist & Haraldson 1984; Enkling et al. 2009).

In this study, the IFDP IFDP showed an average median passive tactile threshold which was 3.5 times higher in CG-CC and 12.5 higher in CG-DD and these...
differences proved highly significant. It is important to note that the passive threshold was much more impaired in IFDP/IFDP than the active tactile threshold. Jacobs reported a 50-fold increase in the mean passive tactile threshold of IFDP/IFDP wearers (Jacobs & van Steenberghe 1993). This difference might be due to the upper cut-off of the stimulus resulting from the force-limit of our gauge at 8 N. The 12.5-fold threshold refers to the mean of median from all six measured sites in all four quadrants of the median of three measurements per site, so that extreme outliers were largely eliminated before averaging the results. When looking at the individual median values per site as depicted in Fig. 4, it becomes clear that individual participants had thresholds which largely exceeded our measuring range.

The question arises whether the nature of the stimulus contributes to difference between the perception of active and passive stimuli. When a patient is asked to bite down, inevitably there is some vibration elicited. By contrast, meticulous care was taken to avoid vibration during the testing of the passive threshold. Furthermore, the coverage of the measuring tip with a polyether material cushioned the vibrations even more than a metal tip. Consequently the differences found in the present experiments support the hypothesis that the muscle spindles, which are known to be sensitive to vibration, play an important role in osseoperception. However, this theory does not explain the large range of sensitivity to passive stimuli found in participants with IFDP/IFDP. These interindividual variations may be related to neuroplasticity which occurs after the loss of teeth and most likely after the placement of dental implants (Sessle et al. 2007; Yan et al. 2008). Little is known on the time scale of neuroplasticity, thus the different delay since the extraction of the last tooth and the placement of the IFDP/IFDP might have played a role.

Concerning the maximum central bite force, no significant difference was shown between the three groups, probably due to the small sample size. A sample size calculation revealed that enrolling 20 participants would have confirmed the common knowledge that complete denture wearers exert lower bite forces than dentate individuals.

One of the hypotheses of the study was that the maximum bite force of subjects with IFDP/IFDP was higher than those found in complete denture wearers. With a slightly larger cohort, the difference between complete denture wearers and dentate subjects would have emerged in the current study, but 968 subjects would have been necessary to evince a different MBF between the complete denture and IFDP/IFDP wearers. In complete dentures, occlusal load is fully transmitted to the denture bearing tissues. The maximum bite force is therefore limited by the pain threshold of the mucosa and the periosteum. In normal chewing, the forces used are further limited by displacement of the dentures when loaded unfavourably. By using the central-bearing point method, such displacement of the denture could be avoided, as occlusal load is distributed evenly to the denture bearing tissues. However, the pain threshold remains a limiting factor. Complete denture wearers “exercise” their jaw closing muscles less and it has been shown that they even loose muscle bulk (Newton et al. 1987). With IFDP/IFDP, occlusal loads are directly transmitted to the bone. Consequently, peristomal pain is no longer a limiting factor for applying occlusal force. It was therefore assumed that the maximum forces used by IFDP/IFDP wearers would be higher than in complete denture wearers. Comments from some patients after the recordings revealed that they did not apply their full force, because they had a previous ceramic fracture experience. Patients with metal ceramic restorations opposing implant-supported dental prostheses experience significantly more often ceramic fractures (Kinsel & Lin 2009), and a fracture history leads to significantly lower voluntary bite forces (Müller et al. 2011).

With the lack of periodontal receptors around the implant, one could assume that the bite force would be higher than in subjects with a natural dentition, because the protective reflexes from the periodontal ligament are missing. Trulsson et al. showed by derivation from individual periodontal receptors that they are mostly sensitive to low pressures under 1 N (Trulsson 2006). Haraldson (1983) found that the muscle force in IFDP wearers during natural chewing adjusted less to the softening of the food than in dentate subjects. Concerning the fine motor co-ordination, we know that subjects with implant-supported reconstructions use more force than dentate volunteers to hold a peanut between the incisor teeth (Trulsson & Gunne 1998). Another interesting finding is that the inhibitory effect could be elicited by tapping individual implants in the upper jaw; however, in edentulous IFDP/IFDP such inhibitory reflex was absent (Bonte & van Steenberghe 1991). These findings confirm the important role of periodontal receptors in the neuromuscular control of the orofacial system. However, the present study confirms that the lack of periodontal receptors does not lead to an uncontrolled and high maximum bite force.

Summary and conclusions

The hypothesis of the present pilot study that edentulous patients rehabilitated with IFDP/IFDPs show an active and passive sensitivity which is lower than in CG-DD but higher than in CG-CC could only be partly confirmed. Whereas the hypothesis is clearly true for the 50% active tactile thresholds, it has to be rejected for the passive sensitivity which proved significantly impaired in comparison with both CG-DD and CG-CC. In a clinical context, purely passive stimuli are rare; consequently, the latter findings are of negligible clinical relevance. The hypothesis that patients with IFDP/IFDP have a higher maximum bite force than both control groups can be rejected on the basis of a sample size calculation, yet a larger cohort is needed for confirmation.

Therefore, it can be concluded that tooth replacement by means of IFDP/IFDP is a valuable alternative to conventional treatment options for the edentulous subject. Nevertheless, this treatment concept still has its limitations with regard to its physiological integration into the orofacial system. Tooth replacement from biomaterials might still be far away from a scientific point of view, but raise hope to overcome these limitations.

Acknowledgements: The authors declare that they have no conflict of interest.

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