Tactile Sensibility of Single-Tooth Implants and Natural Teeth Under Local Anesthesia of the Natural Antagonistic Teeth

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ABSTRACT

Introduction and Aim: The term osseoperception describes the capability of developing a subtle tactile sensibility over dental implants. The present clinical study aims at clarifying the question of how far tactile sensibility is to be attributed to the periodontium of the natural opposing tooth of the implant.

Material and Method: Thirty-two subjects with single-tooth implants with natural opposing teeth were included in this clinical, single-blind, split-mouth study. The natural antagonistic tooth of the implant and the corresponding natural contralateral tooth were anesthetized with a locally infiltrated articaine anesthetic. In a computer-assisted and randomized way, copper foils of varying thickness (0–100 μm) were placed interocclusally between the single-tooth implant and the natural opposing tooth, and between the contralateral pair of natural opposing teeth in order to investigate the active tactile sensibility according to the psychophysical method of constant stimuli and evaluate it statistically by the Weibull distribution.

Results: The average tactile sensibility of the implants with anesthetized antagonists at the 50% value calculated by means of the Weibull distribution was 20 ± 11 μm with a support area (90%–10% value) of 77 ± 89 μm. For the pair of natural teeth, the tactile sensibility at the 50% value was 16 ± 9 μm with a support area of 48.4 ± 93 μm. This resulted in an average intraindividual difference of 3.5 ± 7 μm at the 50% value and 29 ± 93 μm in the support area. The statistical calculations demonstrated an equivalent tactile sensibility (50% value) of the single-tooth implant and the contralateral natural control tooth with the natural antagonists being anesthetized in each case (double *t*-test, equivalence limit ± 8 μm, $P < 0.01$, power >80%).

Conclusion: Apparently, the active tactile sensibility of single-tooth implants with natural opposing teeth is not only to be attributed to the periodontium of the opposing tooth but also to a perception over the implant itself. This could support the hypothesis according to which the implant may have a tactile sensibility of its own.

KEY WORDS: active tactile sensibility of dental implants, interocclusal perception of teeth and implants, osseoperception, single-blinded randomized clinical split-mouth trial, steepness of the sensibility curve, support area, tactile sensibility under anesthesia

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INTRODUCTION

The capability of osseointegrated titanium implants to transmit a certain sensibility or otherwise known as "osseoperception" as coined by Brånemark, has been the subject of numerous publications in the past few years.[1–8] The physiological basis of osseoperception is not yet fully known. Two concepts are discussed, that is, an activation of local receptors in the bone[9] and an activation of more remote receptors.[10]

The oral perception sensibility of dental implants can be tested either by passively applying pressure on the occlusal surface of the implant, that is, passive tactile sensibility, or by having the test persons bite on thin test bodies, that is, active tactile sensibility.[4,11] The results for passive tactile sensibility are expressed by the minimum pressure that was perceived through the implant (N). Active tactile sensibility is expressed by the thickness of the thinnest foreign body perceived (µm). Studying passive tactile sensibility only allows to test individual neural receptors, whereas, active tactile sensibility more effectively represents normal function and is therefore more interesting for practical dentistry.[12,13]

However, results of the studies dealing with passive and active tactile sensibility are contradictory. As far as active tactile sensibility is concerned, it could be shown that the interocclusal perception sensibility of single-tooth implants when occluding against natural antagonists and of the remaining natural dentition are equivalent ($P < 0.01$, power >80%).[14] In passive tactile sensibility studies, the implants were clearly less sensitive than the teeth selected for comparison; the values for passive tactile capability were higher by a factor of 8 to 10, and in some cases they were 50 times higher.[15–17] Very small static pressures cannot be felt through osseointegrated implants, but greater static and dynamic loads (= vibrations) in axial and horizontal direction can be felt.[18] When the pressure stimuli go beyond a certain threshold, the capability of discriminating between forces of different magnitude is almost the same for implants and teeth.[19] When passive tactile perception was tested with and without local infiltration anesthesia of the periimplant tissue and with and without a prosthetic abutment, which prevented any contact with the soft tissue, it was shown that the removal of the abutment and the local anesthesia had no influence on the perception thresholds under static and dynamic loads on the implants. In the case of natural teeth, however, passive tactile perception was significantly worse under soft tissue anesthesia. The anesthesia inactivated the periimplant receptors of the gingiva, mucosa and periosteum, and around the natural teeth. Additionally, it also inactivated the receptors in the periodontium and in the pulp of the tooth. Under static passive loads, the results of anesthetized teeth and implants reached about the same values of approximately 6 N.[18] By using different types of periimplant local anesthetization it could be shown that the passive tactile capability of implants is probably to be attributed to receptors in the bone rather than to mucosal receptors.[20,21]

The difference between the active and passive tactile perception of implants can be explained by the fact that in the active test, various groups of receptors are activated; whereas the passive test selectively addresses the receptors in the periodontal ligament which are missing after the extraction of the tooth that was previously in the region of the implant.[16,22] However, several studies demonstrate that, although the periodontal fiber apparatus is missing, the tactile sensibility will increase when prosthetic restorations are placed on the implants and that implant-supported restorations are superior to mucosa-supported restorations with regard to both stability and tactile sensibility.[11,23,24]

Thus, regarding the active tactile perception of single-tooth implants with a natural opposing tooth, the question has to be clarified in how far the tactile perception is to be attributed to the periodontal receptors of the natural antagonist.[25]

AIM

The aim of the present study was to get more information about the neurophysiological mechanisms of osseoperception and the relevance of periodontal mechanoreceptors to oral tactile sensibility. Therefore, in the present study, using a split-mouth experimental set-up, the active tactile sensibility of a single-tooth implant was compared with that of the remaining natural teeth on the contralateral side. The study compared, in the same individual, the active tactile sensibility of the combination of a single-tooth implant and a natural antagonistic tooth with the active tactile sensibility of the occlusion of two natural teeth on the contralateral side. The experiment was performed with anesthesia being applied to the antagonistic natural teeth on both sides.

MATERIAL AND METHOD

Cohort

Thirty-two subjects with single-tooth implants were included in the study. Sites of the implants were in the upper jaw ($n = 12$), in the lower jaw ($n = 20$), in the front region ($n = 10$), and in the posterior region ($n = 22$).

The test persons had a mean age of 38.9 years ± 11.5 (min. 25 and max. 63 years), and the gender distribution was 24 women and 8 men. All tested implants and teeth regarding the common criteria[26–28] were healthy and without any pain or inflammation.

Method

For local anesthetization of the antagonistic teeth, we used ultracaine DS forte® (articaine 4% with epinephrine 1:100,000, Sanofi-Aventis, Meyrin, Switzerland) given at least 5 minutes before starting the examination. Orally 0.3–0.7 mL and buccally 1.0–1.2 mL of local anesthetic was applied. The success of the anesthesia was confirmed by a negative response to pressure and cold stimulus (Coolan®, Voco, Cuxhaven, Germany). The anesthesia was performed separately on both sides before the examination so that the risk of side effects or insufficient anesthetization was minimized. Interocclusal 5–100 µm copper foils were positioned on the teeth of the test persons who were asked to bite briefly on them and indicate whether or not they felt the foreign bodies. As foreign bodies between the teeth cannot only be felt when biting on them but also heard via bone conduction, earphones were placed on the ears of the test persons which transmitted "white" and "pink" noise from a cassette tape recorder at the highest possible sound volume. Via a mixing console and a microphone, the examiner had the possibility of giving instructions to the test persons through the earphones.

The foil thicknesses at which, according to the relevant literature, the threshold value of the tactile sensibility was assumed to be reached were tested by a greater number of repetitions. The sequence of foil thicknesses and interspersed "placebo foils" for every 232 test runs per test person as well as the test site, that is, the implant region or the contralateral pair of teeth at which the testing was started, were randomized. By pressing the keys of a computer mouse, the patient indicated after every round whether or not he had felt something between his teeth. This output was stored directly in the computer categorized by foil thickness (MedStats®, University of Bonn, Bonn, Germany). Ethical approval for the study was obtained from the ethics commitee of the Faculty of Medicine, University of Bonn.

Statistical Evaluation

The statistical evaluation was done with the SAS 8.2 software (SAS Institute, Inc., Cary, NC, USA). All test results recorded were included in the evaluation and analyzed by the asymmetric Weibull distribution, which was the best-fitting psychometric function for the active sensibility curves. The definition for the oral perception sensibility was the estimated 50% value of correct answers. Beside the 50% value, the sensibility curve was also described by the support area (the width of the area between the 10% value and the 90% value) as a characteristic of the slope of the tactile sensibility curve. A small support area represents a steep slope of the curve and vice versa.

The primary endpoint of the clinical trial was the intraindividual comparison of the 50% values of implant and pair of control teeth, expressed by their difference (50% value implant side – 50% value natural tooth side). As a symmetric distribution of the intraindividual differences was assumed, the double *t*-test was used for the equivalence hypothesis.[29,30] By analogy with the thinnest occlusal foil used, the equivalence margins were fixed at 8 mm. Sample size calculations were performed with the data of a previous study[14] using the Kieser & Hauschke formula,[31] assuming a statistical power > 80% and alpha = 0.05. Additionally, the following variables were evaluated in a descriptive manner for their potential influence on tactile sensibility:

- Age of the test persons;
- Gender of the test persons;
- Location of the tooth or implant (anterior/posterior region; upper/lower jaw);
- Period of edentulism in the region where the implant was placed later on;
- Period of prosthetic function of the implant.

RESULTS

The mean thresholds (50% value) of the oral perception sensibility were 19.7 ± 11 µm for the implant side and 16.1 ± 9 µm for the control-tooth side. The mean intraindividual difference for the 50% values was 3.5 ± 6.8 µm. The values for the intraindividual difference were around 0 µm and ranged between –12.37 µm and 20.19 µm. The statistical test for equivalence of the 50% values on the implant side versus the control side showed a significant level ($P < 0.01$) within the range of [–8 µm; +8 µm].

The support area (90%–10% value) on the implant side was 77 ± 89 µm, for the teeth it was 48.4 ± 93 µm. For the support area, the average intraindividual

TABLE 1 50% Values (μm), Support Areas, and Intraindividual Differences of the Implant Side and the Control Tooth Side

	n	Mean (μm)	SD	95% CI	Min. (μm)	Median (μm)	Max. (μm)
50% value implant side	32	19.7	11.1	[15.7; 23.7]	0.4	19.7	46.8
50% value tooth side	32	16.1	9.4	[12.7; 19.5]	1.5	14.7	36.3
Difference 50% value (implant side – tooth side)	32	3.5	6.8	[1.1; 6.0]	−12.4	2.7	20.2
Support area implant side	32	77.0	88.6	[45.1; 109.0]	9.1	57.5	541.2
Support area tooth side	32	48.4	25.1	[39.4; 57.5]	12.2	46.6	99.7
Difference support area (implant side – tooth side)	32	28.6	93.3	[−5.1; 62.2]	−37.7	13.6	515.1

SD, standard deviation; CI, confidence interval.

difference between the implant and the control side was 29 ± 93 μm (see Table 1 and Figure 1a,b).

Statistically, on the control side, the tactile sensibility of the anterior teeth (10.3 μm ± 4.7) was significantly greater than that of the posterior teeth (18.8 μm ± 9.9) ($P = 0.017$). There was also a difference between anterior implants (15.4 μm ± 7.9) and posterior implants (21.6 μm ± 11.9), but not at a statistically significant level ($P = 0.150$; see Table 2). The parameters of the subjects' age and gender, period of edentulism and prosthetic load did not have any influence on tactile sensibility.

DISCUSSION

The sample size of the study was calculated with the data of a previous study[14]: Thirty test subjects were calculated as being sufficient to prove the primary hypothesis. Because no gender dependency of the tactile sensibility results was expected,[14] the imbalance in the gender distribution of our sample was accepted. Also, the results of the present study showed no gender dependency.

As foreign bodies between the teeth cannot only be felt but also heard by bone conduction, when the teeth occlude, the subjects were exposed to special noise through earphones.[13,32] It may be assumed that this measure limited their perception to the sense of touch.[33] In the final interviews, the subjects confirmed that they did not hear the biting on the foils. The chewing pressure and dynamics of tactile motions, however, could not be standardized. The test strips were manufactured from high-precision copper foils that adapt to the occlusal relief because of their high ductility. This ensured that the intended interocclusal clearance could be achieved during testing with the highest possible precision.[13,14] However, the possibility that thermal sensations were transmitted to the teeth being tested cannot be ruled out because of the thermal conductivity of the copper material used. This could then distort the absolute values measured.[34] As the study was conducted at an ambient temperature of approximately 25°C, the resulting thermal reaction could only be very minor. An experimental setup with decreasing foil thickness, often used in the past, leads to a learning curve and thus to better results for thinner foils.[35] In the present study, these effects on the 50% values were compensated by randomizing the foil thickness. The study design conforms to the requirements for psychometric trials with the method of constant stimuli.[10,36]

The local anesthetization of the natural antagonistic teeth inactivated their periodontal and pulpal receptors during the test,[37] so that, on the side of the control teeth, only one periodontium, rather than two, as would be the case in the non-anesthetized condition, could send signals to the central nervous system (CNS) about the interocclusally positioned foreign body. Articaine with an added vasoconstrictor is a very potent and quick-acting local anesthetic with proven safe and reproducible inactivation of periodontal and pulpal receptors through buccal and oral infiltration anesthesia[38–40] and with a sufficiently long period of action for the test that lasted about 45 minutes per side.[41–44] The effect of the anesthesia cannot be identified in an objective unbiased way without expensive and complex equipment. Therefore, a probe test (sticking a pointed probe in the mucosa) and a cold test (applying a cold cotton pellet to the tooth) appeared to be the only practical possibility of testing the anesthesia.

Under local anesthesia of a tooth, the reduction of the masticatory muscle activity resulting as an adverse-

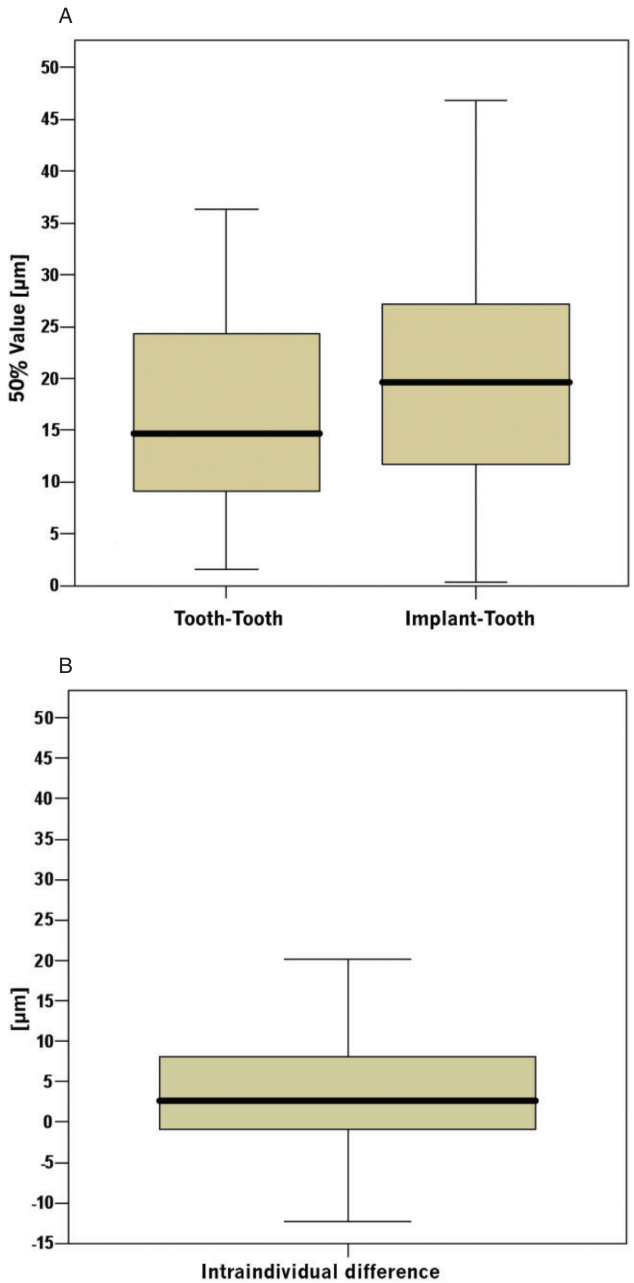

Figure 1 *A*, 50% values (μm) of the implant side and the control tooth side. *B*, Intraindividual difference between the implant side and the control tooth side.

effects reflex from an occlusal load will decrease by about 90%.[45] This proves the importance of the periodontium for the somatosensorial control loop.[10,46] As a consequence, the joint and muscle receptors are assumed to play a minor role in connection with tactile perception[47,48] and are important especially when the mouth is wide open.[49–51] In the incisor and cuspid region, the interocclusal tactile sensibility was not tested in maximum intercuspation of the mandible as the precise interposition of the foils would not have been possible in that mandibular position. Moreover, the teeth would have been loaded rather horizontally. Yet, it cannot be excluded that the mandibular testing position had an influence on the results. The result of the present study, according to which the tactile sensibility was greater for the anterior than for the posterior teeth, may have been due to the different jaw positions during the test and point to the relevance of the muscle and joint receptors. Although in the test setup, the periodontal receptors were halved, as described, the active tactile perception of 16.1 ± 9 μm on the side of the control teeth almost invariably reached the same level as the tactile perception of pairs of non-anesthetized teeth reaching 14.3 ± 10.6 μm.[14] These results agree with statements in the literature according to which a reduction of the periodontium caused by periodontitis will not lead to a loss of tactile sensibility.[52,53] Thus, the periodontium of the non-anesthetized opposing tooth in combination with the temporomandibular joint and muscle receptors is a sufficient source of information for the CNS which might indicate a certain degree of redundancy of the stomatognathic control loop.

The 50% values on the implant side in the present study, that is, 19.7 ± 11 μm, are very similar to the values of 16.7 ± 11.3 μm for single-tooth implants with non-anesthetized natural antagonists.[14] The intraindividual difference between implant side and control tooth

TABLE 2 50% Value (μm) of the Implant Side and the Control Tooth Side: Divided into Front and Side Teeth Region

	n	Mean (μm)	SD	95% CI	Min. (μm)	Median (μm)	Max. (μm)
Front tooth region: tooth	10	10.3	4.7	[6.9; 13.7]	3.1	10.9	18.2
Side tooth region: tooth	22	18.8	9.9	[14.3; 23.2]	1.5	18.1	36.3
Front tooth region: implant	10	15.4	7.9	[9.7; 21.2]	1.6	17.6	26.8
Side tooth region: implant	22	21.6	11.9	[16.3; 26.9]	0.4	23.8	46.8

SD, standard deviation; CI, confidence interval.

side was 3.5 ± 6.8 μm with anesthesia and 2.4 ± 9.4 μm without anesthesia. The periodontal receptors of the opposing teeth, which were inactivated by local anesthesia in the present study, seem to have a minor influence on active tactile sensibility and/or may be replaced by the perception through the implant as a result of the redundancy mentioned.

The evaluation of the results for the support areas indicates differences between the implant and the control tooth side in the present study. In a test subject with a flat slope, that is, a low value of the slope and a large support area, the 50% value represents a point along a slowly rising curve; whereas in a test subject with a steep slope, that is, a high value of the slope and a small support area, the 50% value is more of a true threshold. Thus, the slope of the curve is a yardstick for the reliability of the subject's decision: "yes, I've felt something," or "no, I didn't feel anything." The mean support area for the implant side was 28.6 μm larger than the support area for the control tooth side. This means that the sensibility curves of the teeth had a steeper slope than those of the implants, so that the certainty of feeling foreign bodies seemed to be more pronounced for natural teeth than it was for implants.

Nevertheless, the oral perception of single-tooth implants and of natural teeth with anesthetized natural antagonists is within the equivalence range of ±8 μm statistically equivalent ($P < 0.001$, Power > 80%), and with mean values below 20 μm very fine.

OUTLOOK

Similar resulting 50% values, but with differences in the support areas, indicate physiological differences as the cause for the tactile sensibility of implants and teeth. The periodontal receptors of the antagonistic teeth seem to do little to impact the capacity of oral implants to transmit the active tactile sensibility. In addition to the mechanoreceptors of the chewing muscles and of the temporomandibular joint,[54] the implant may have a perception capability of its own, which is called osseoperception. The periimplant tissue, that is, jawbones and soft tissues around the implant, seem to be of importance for the sensibility of implants. Additional studies dealing with the physiological basis of osseoperception therefore appear to be appropriate.[22]

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