Changes in Passive Tactile Sensibility Associated with Dental Implants Following Their Placement

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Purpose: *This study investigated the changes that might occur in passive tactile sensibility during a period of 3 months following implant placement in a group of edentulous subjects treated with dental implants. The effect of changing the velocity of force application on passive tactile sensibility was also investigated.* ***Materials and Methods:*** *Five edentulous subjects who had been treated (as a part of an immediate loading study) with 2 or more Nobel Biocare dental implants in the anterior mandible were studied. Pushing forces were applied directly and perpendicular to the long axes of the abutments until the subjects felt the first sensation of pressure, using a computer-controlled, custom-made device. The force was measured with an integral transducer. The applied force had a ramped staircase pattern, which was used at 2 different tip velocities. The measurements were taken on 4 occasions: 1, 2, 4, and 12 weeks after fitting the abutments.* ***Results:*** *Statistical analysis, using multilevel modeling, demonstrated that there was a significant decrease in the tactile threshold over successive weeks following implant placement. It also demonstrated that high velocity exhibited a higher threshold than low velocity.* ***Discussion and Conclusion:*** *It could be concluded that there was a significant increase in passive tactile sensibility during the healing phase following implant placement.* (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:266–272)

Key words: *dental implants, passive tactile sensibility, sensory thresholds*

Following tooth extraction, the periodontal ligament disappears together with, it is thought, its neuroreceptors, leading to significant sensory deprivation. Placement of dental implants to provide anchorage for implant-supported overdentures or fixed prostheses has increasingly dominated treatment strategies for the last 2 decades.[1,2] Passive tactile sensibility has been defined as the detection of minimum forces applied directly to the teeth or implants in a vertical or horizontal direction.[3] For natural teeth, passive tactile sensibility depends on the presence of periodontal ligament receptors. A reduction in passive tactile sensibility may be assumed in subjects with partial or complete loss of the periodontal ligament.[4]

The loading velocity is one of various factors that influence the tactile threshold of passive tactile sensibility.[5] van Steenberghe and de Vries[6] and van Steenberghe and coworkers[7] found higher threshold values with lower stimulus velocity. For mechanical force application, the use of pushing as opposed to tapping forces applied directly between the abutments was intended to maximize discrimination of the receptors in the peri-implant area from more distant receptors.[8]

Keller and associates[9] reported that despite ongoing osseointegration and remodeling of the bone during the healing phase of implant treatment,

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the tactile threshold did not change significantly. Few data are available on this phenomenon. The aim of this study was to investigate the potential changes that might occur in passive tactile sensibility associated with dental implants during a period of 3 months following implant placement. To accomplish this, pushing forces were applied directly and perpendicular to the long axes of the implant abutments. The effect of changing the velocity of force application on passive tactile sensibility was also investigated.

MATERIALS AND METHODS

The test group consisted of 5 edentulous subjects who had been treated with at least 2 dental implants (Nobel Biocare, Göteborg, Sweden) in the anterior region of the mandible. These subjects were treated in the Department of Prosthetic Dentistry at Eastman Dental Hospital (London, England) and the implants were loaded immediately following initial soft tissue healing. Three were men and 2 were women; their mean age was 66.2 years (SD 7.1), with a range of 56 to 78 years. All subjects had been partially dentate in the mandible for at least 10 years and edentulous in the mandible for more than 6 years (subjects 1 and 2), more than 5 years (subject 3), more than 3 years (subject 4), and more than 4 years (subject 5). All had at least 2 implants of the same length on opposite sides of the mandible. The transmucosal abutments (TMAs) connected to these 2 implants were parallel to each other (within ± 5 degrees) to ensure that the force was applied perpendicular to the long axes of the implant TMAs. The subjects provided no evidence of local or systemic disease that might have influenced the outcome of the study, and all gave informed consent for participation in the study, which had approval from the local ethical committee.

Loading was by means of a precision custom-made device (Fig 1). This loading device was designed and constructed to apply pushing forces to dental implants at the chairside. It was driven by a stepper motor using commercial control boards in a unit designed and built as part of the study. The motor was computer-controlled, and all devices were operated at low voltage. The forces were measured with a strain-gauge transducer mounted on the device. The pushing forces applied directly between the abutments had a ramped staircase pattern, which was used at 2 different tip velocities (0.03 mm/s and 0.3 mm/s), producing 2 loading profiles (loading profiles 1 and 2, respectively).

Fig 1 The loading device.

These had been selected as the most suitable profiles in a separate pilot investigation.

The subjects resumed using their old conventional dentures, after relining with a soft lining material, 2 weeks after implant placement. Measurements of the tactile threshold were started 1 week after connecting the TMAs to the implants (ie, after making the secondary impressions), 5 weeks after implant placement.

The experiment was carried out in a quiet room. Each subject was comfortably seated in a dental chair in an upright position with his/her head resting against the head support. Two Nobel Biocare square impression copings were fitted onto the abutments. The force sensor was adjusted to ensure that electrical zero occurred before the grooves of the loading probes of the loading device were brought into light contact with the notches of the impression copings. The device was carefully held by hand at right angles to the long axes of the impression copings. Contact between the lips and any part of the device was avoided to prevent triggering the remote receptors.

The force amplitude was increased in discrete steps until the subjects felt the first sensation of pressure, which they indicated using a finger-operated microswitch. The time lag of the subject's reflex was not measured. The applied force was measured continuously with the force sensor and recorded electronically for subsequent analysis.

Before the assessment of threshold values, each subject underwent a training session to become

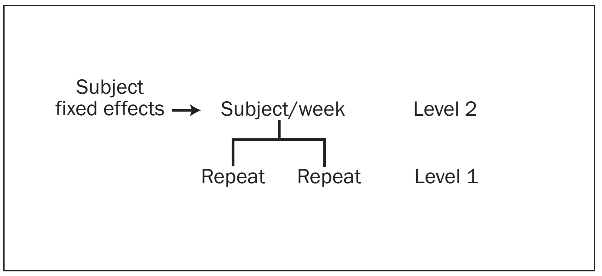

Fig 2 The generic 2-level data structure.

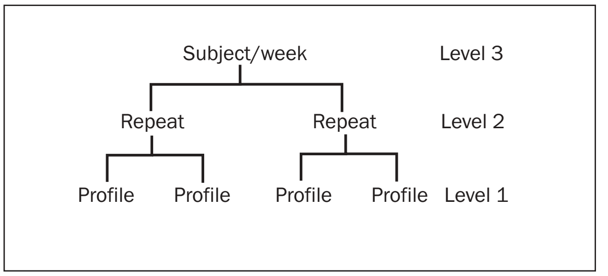

Fig 3 The multivariate 3-level data structure.

accustomed to the loading device and to practice detection of the threshold forces. The subject was then allowed to rest for at least 15 minutes before 5 measurements for each loading profile were made at intervals of at least 2 minutes between each measurement, with a rest period of 5 minutes between each of the 2 loading profiles. Loading was carried out in the same sequence for each subject, going from loading profile 1 to loading profile 2. The measurements were repeated for each subject on 4 occasions (1, 2, 4, and 12 weeks) after connecting the abutments to the implants. The recorded measurements were analyzed using the statistical procedure of multilevel modeling (MLM).[10]

The loading device was calibrated before and after each recording session to confirm its linearity and reproducibility using a series of weights (0.2 to 1.8 kg). This procedure was repeated 10 times for each weight. These data were then used to calculate the forces applied by the loading device.

Statistical Analysis

The outcome of this study was the determination of tactile threshold, as detected by edentulous subjects experiencing pushing forces on the implants, during a period of 3 months following their placement. The duration in weeks since implant placement, loading velocity, and repeated measurements were the only factors that were considered to influence the tactile threshold. The data collected therefore comprised repeated measurements (5 recordings taken consecutively) for 2 loading profiles (1 and 2) carried out for 5 edentulous subjects on 4 occasions (1, 2, 4, and 12 weeks after abutment connection) after implant placement. The use of MLM was appropriate for analyzing such a clustered data set, and 2 approaches were adopted: the standard multilevel process (which considered the generic hierarchy) and the multivariate multilevel process (which separated out the data into 2 outcomes, 1 for each loading profile).

The Standard Multilevel Process. Because there were only 5 subjects at the uppermost level (ideally at least 20 subjects are required for MLM or related methods such as analysis of variance [ANOVA]), the subject level of the hierarchy was omitted and combined with the level of successive weeks. Subject differences were therefore modeled as fixed effects, through treating each subject identifier as a covariate. The model hierarchy is shown in Fig 2.

Initially, the variance components (VC) model (ie, no covariates included) was evaluated for the 2-level data structure in Fig 2, which was then developed to include subjects as fixed effects. Time since implant placement in weeks (operating at the subject/week level), along with loading profiles and repeated measurements (both operating at the repeat level), were then explored separately as potentially important covariates. The effect of successive measurements over the weeks following implant placement was modeled through the inclusion of linear and quadratic time-varying covariates "centered" on week 4. Repeated measurements were investigated similarly with time-varying covariates centered on repeat 3. All covariates were subsequently considered in a single final model where covariate coefficients were also explored for random effects[11] (model I).

The Multivariate Multilevel Process. It is possible and often useful to partition the data into separate key outcomes. In this instance, independent outcomes were considered for each loading profile. Again, subjects were modeled as fixed effects, with the resultant multivariate multilevel data structure shown in Fig 3.

The VC model was evaluated for the 3-level data structure (Fig 3) and subject fixed effects were then included. The covariates for "week" and "repeat measurements" were explored separately as potentially important factors. All covariates were subsequently considered together in a single final model where random coefficient effects were also explored (model II).

Table 1 Means, SDs, and Ranges of the Tactile Threshold Detected by the 5 Subjects in Response to the 2 Loading Profiles on 4 Occasions

	Tactile threshold (N)		
Loading profile	Mean	SD	Range
Loading profile 1 (low-stimulus velocity)			
1 week	13.6	3.3	7.9–16.7
2 weeks	11.9	2.6	7.5–15.1
4 weeks	10.3	2.8	6.6–14.1
12 weeks	8.5	3.0	5.0–13.0
Loading profile 2 (high-stimulus velocity)			
1 week	15.0	3.3	8.8–17.8
2 weeks	14.6	3.3	8.4–17.4
4 weeks	13.2	3.3	8.2–16.6
12 weeks	11.4	3.7	6.7–16.0

RESULTS

Quantitative Analysis

The means, standard deviations, and ranges of the threshold values detected in response to loading profiles 1 and 2 on 4 occasions (1, 2, 4, and 12 weeks) following implant placement are presented in Table 1.

The results are presented in Figs 4 and 5. The x-axis represents the week, while the y-axis represents the mean (of the 5 recorded threshold values) in Newtons detected by each subject in response to 1 loading profile.

It can be seen from Figs 4 and 5 that there were large variations within and between subjects. The mean threshold values decreased on average over the successive weeks following implant placement in all subjects. The mean threshold values were lower

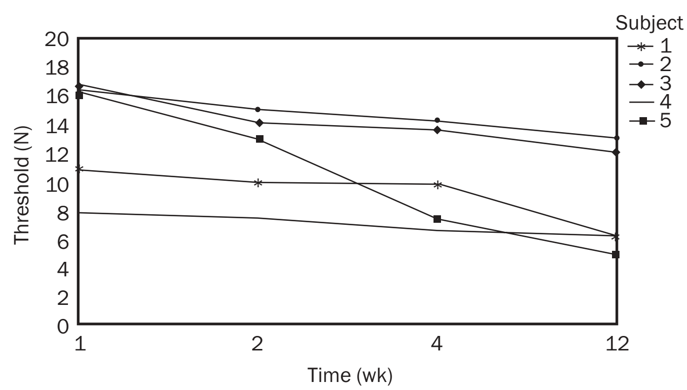

Fig 4 The mean of 5 measurements of the tactile threshold detected by each subject in response to loading profile 1 on 4 occasions (1 week, 2 weeks, 4 weeks, and 12 weeks).

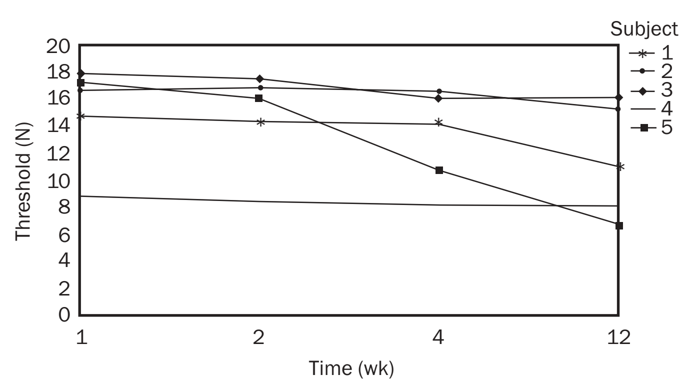

Fig 5 The mean of 5 measurements of the tactile threshold detected by each subject in response to loading profile 2 on 4 occasions (1 week, 2 weeks, 4 weeks, and 12 weeks).

Table 2 Multilevel Model (Model I) Assessing the Association Between Tactile Threshold and All Covariates Simultaneously for the 2-Level Structure (Including Random Coefficient Variation)

	Coefficient (standard error)	P value
Fixed effects		
Intercept	9.013 (1.092)	< .001
Subject—reference: Subject 1		
Subject 2	4.648 (1.252)	< .001
Subject 3	4.455 (1.252)	< .001
Subject 4	–3.032 (1.252)	< .001
Subject 5	0.654 (1.252)	.601
Profile	2.474 (0.306)	< .001
Week—linear	–0.754 (0.252)	.003
Week—quadratic	0.067 (0.042)	.109
Random effects		
Variances		
Subject/week level		
Variance (intercept)	3.303 (1.047)	.002
Variance (profile)	–0.565 (0.572)	.322
Covariance (intercept, profile)	1.864 (0.592)	.002
Repeat level—variance (intercept)	0.023 (0.003)	< .001
Total unexplained variance*	6.489	

*The total variation is a combination of twice the covariance term plus each variance term.

Table 3 Multivariate Multilevel Model (Model II) Including All Covariates for the 3-Level Data Structure

	Coefficient (standard error)	P value
Fixed effects		
Profile 1	8.261 (1.075)	< .001
Profile 2	13.231 (1.107)	< .001
Subject/profile 1—ref:1		
2	5.462 (1.236)	< .001
3	4.892 (1.236)	< .001
4	–2.124 (1.236)	.086
5	1.305 (1.236)	.291
Subject/profile 2—ref: 1		
2	2.766 (1.273)	.029
3	3.434 (1.273)	.007
4	–5.132 (1.273)	< .001
5	–0.859 (1.273)	.499
Week/profile 1—linear	–0.859 (0.249)	< .001
Week/profile 1—quadratic	0.081 (0.041)	.049
Week/profile 2—linear	–0.513 (0.256)	.045
Week/profile 2—quadratic	0.035 (0.043)	.414
Random effects		
Subject/week level		
Profile 1	3.049 (0.890)	< .001
Profile 2	3.236 (0.945)	< .001
Covariance (profile1, profile 2)	2.918 (0.882)	< .001
Repeat level—variance (intercept)		
Profile 1	0.023 (0.004)	< .001
Profile 2	0.023 (0.004)	< .001
Covariance (profile 1, profile 2)	—	—
Total unexplained variance*	12.167	

*The total variation is a combination of twice the covariance term plus each variance term.

in response to the loading profile with low tip velocity (ie, loading profile 1) than the loading profile with high tip velocity (ie, loading profile 2) in all subjects.

Statistical Analysis Using MLM

The Standard Multilevel Process. The final standard multilevel model (model I) is shown in Table 2. As might be expected, there were some significant differences in threshold values across subjects. The loading profile showed a highly significant ($P < .001$) association with tactile threshold; loading profile 2 exhibited a higher threshold level than loading profile 1. There was also a significant decrease in tactile threshold over successive weeks following implant placement, indicated by the negative coefficient (–0.754) for the linear time-varying covariate for week. The threshold reduced week by week but at a slowing pace, indicated by the positive quadratic time-varying covariate (0.067), though this latter coefficient was not significant at the 5% level ($P = .109$). There were no significant changes in tactile threshold across repeated measurements at each assessment, which is why this was omitted completely from the final model.

Random coefficient variation was exhibited by the covariate for profile across the subject/week level, indicating that the influence of profile on the outcome varied across weeks and between subjects. Thus, the difference between the 2 profiles was not consistent over time and/or across subjects.

The Multivariate Multilevel Process. The final multivariate model (model II) is presented in Table 3. Marked differences were observed between profiles (8.261 for loading profile 1 and 13.231 for loading profile 2). Furthermore, differences across subjects varied between profiles, eg, profile 1, subject 2 exhibited a higher threshold difference (5.462) than subject 3 (4.892), whereas for profile 2, the pattern was reversed, with subject 3 having a higher threshold difference (3.434) than subject 2 (2.766).

Tactile threshold reduced week by week, as indicated by the negative linear week coefficients (–0.859 and –0.513 for loading profiles 1 and 2, respectively). However, the rate of reduction diminished, indicated by the positive quadratic coefficients (0.081 and 0.035, respectively). However, the quadratic time-varying covariate for loading profile 2 was not significant at the 5% level (P = .414). There were no significant time-varying effects across repeated measurements for either profile; hence, these were omitted completely from the final model. No significant random coefficient effects were found for this model.

DISCUSSION

There was a significant (P < .001) decrease in the tactile threshold over the successive weeks following implant placement. This finding contradicts that of Keller and coworkers,[9] who found that the tactile threshold associated with dental implants was not affected by bone and soft tissue healing during the phase of osseointegration. Their explanation for these results was that possible changes taking place may have been below the detection level of the method used, or that actual changes did indeed take place, but may have been limited to the first week following implant placement.

The finding in the present study could be explained by the presence of periodontal receptors that may not be totally destroyed and therefore could still evoke a response in the mesencephalic nucleus when stimulated, as reported by Mason and Holland.[12] Since dental implants are firmly anchored in the jaw bone, it is possible that receptors in the bone surrounding the implant may increase mechanoreceptive sensibility. All the patients were able to feel the forces applied to the implants. Several reports have suggested that possibly a sufficient number of receptors are retained in the surrounding tissues.[13–15]

The mechanism for passive tactile sensibility appears to be fully functional during a period of 3 months after implant placement, indicating the presence of adequate compensatory mechanoreceptors in the tissue surrounding the implants (eg, receptors in the bone and soft tissues). The reported tactile thresholds in the present study were somewhat higher than those of the previous report by Keller and coworkers.[9] This could be attributed to the different implant system used for assessment.

Within the multilevel statistical analysis, the direct consequence of reducing the hierarchy was that subject-level covariates such as age, gender, implant length, and separation could not be explored as covariates.

Loading velocity had a highly significant (P < .001) association with tactile threshold. The higher the velocity of the applied load, the higher the threshold value recorded. This could be the result of lack of maturation of osseointegration in the early stages of implant treatment (ie, the implant is less stable) and may reflect the viscoelastic nature of bone, which could result in less deformation at higher loading rates. Within the standard multilevel process, the inclusion of random coefficient variation gave rise to attenuated subject fixed effects, suggesting that complex profile variation was occurring across subjects. The multivariate model confirmed this, as subjects responded differently from each other, and these differences varied across both profiles. It may therefore be concluded that on certain weeks and for some subjects, tactile threshold varied more for loading profile 1 than for loading profile 2. In other words, the amount of outcome variation over the weeks and across all subjects depended on the profile adopted (ie, the velocity of load application).

There were no significant changes in subject response to either profile across the repeated measurements. This indicates that, for this group of subjects, there was either no increasing "familiarity" with the testing process or no progressive improvement in response threshold, thus, subjects did not learn to recognize the stimulus with each repeated test.

A study of this type provides limited information that is of direct clinical applicability; however, the relationship between passive tactile sensibility and presumed maturity of osseointegration could, with further investigation, prove valuable as a diagnostic tool in determining implant status.

CONCLUSION

It could be concluded from this study that there was a significant increase in passive tactile sensibility during a period of 3 months following implant placement in subjects treated with an immediate loading regime for their implants. This study also demonstrated that load application with a higher velocity produced a higher tactile threshold than load application with the lower velocity. It could be postulated that receptors in the peri-implant area have a significant influence on passive tactile sensibility associated with dental implants.

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