Perception by Osseointegrated Dental Implants Supporting a Fixed Prosthesis: A Prospective Study

Purva V. Bakshi, MDS[1]/Srinath Thakur, MDS, FDSRCPS[2]/Sudhindra Kulkarni, MDS[3]

Purpose: *Osseointegrated implants have been shown to transmit a certain sensibility termed as osseoperception. The purpose of this study was to determine the perception by implants over a period of 6 months after loading in comparison to the natural dentition.* ***Materials and Methods:*** *Twenty subjects (ages 40 to 50 years) were included in this split-mouth clinical trial. The subjects were divided into two groups (n = 10) as follows: group 1—subjects with recently cemented implant-supported fixed prosthesis opposing natural teeth; group 2—subjects with recently cemented implant-supported fixed prosthesis in both arches. The implant-supported prostheses were considered as the test sites, whereas natural teeth on the contralateral side were considered as the control. Articulating papers of varied thickness were placed interocclusally in the posterior region in a predetermined random order of true and false insertions. The subjects' ability to perceive the presence/absence of the test papers was recorded for every insertion. The evaluation was performed immediately after cementation and at 1 week, 3 months, and 6 months after cementation. The minimum interocclusal thickness detected by the subjects at the test and control sites at different time intervals was used for further analysis.* ***Results:*** *All subjects with implant-supported prostheses perceived a certain thickness of articulating paper. The minimum interocclusal thickness detected by the implant-supported prosthesis decreased postloading; however, the difference was not statistically significant ($P > .008$). At the end of the follow-up period, the minimum interocclusal thickness detected by the implants in group 1 was similar to the controls, whereas it was significantly higher than the controls in group 2 ($P < .05$).* ***Conclusion:*** *There was progressive improvement in the perception by implant-supported prostheses during the follow-up period, and it was nearing the perception by natural teeth in subjects with implants opposing natural teeth.* INT J ORAL MAXILLOFAC IMPLANTS 2017;32:1346–1350. doi: 10.11607/jomi.4515

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Amputees and edentulous patients restored with bone-supported prostheses have reported a specific feeling around the endosseous implants.[1] Bone-anchored limb prostheses have better perception for vibrotactile and pressure stimulus than socket prostheses.[2] Similarly, several previous studies have described a specific feeling and perception of mechanical stimuli by osseointegrated oral implants.[3–6]

This capability of osseointegrated titanium implants to transmit a certain sensibility is termed "osseoperception."[7,8] Osseoperception can be defined as a conscious perception of external stimuli transmitted via bone-anchored prostheses by activation of neural endings and/or receptors in the peri-implant environment.[9]

Sensory inputs from the oral cavity guide mandibular movements and are essential for the optimal functioning of the oral masticatory apparatus. The periodontal and nonperiodontal receptors play a role in the interocclusal discrimination of objects. The nonperiodontal receptors such as muscle spindles and articular receptors play a role only when the interincisor distance is more than 5 mm. However, input from the periodontal region is important for accurate interocclusal microthickness perception.[10] Among the various theories proposed to substantiate the phenomenon of osseoperception, there is accumulating laboratory evidence that nerve endings exist in the peri-implant bone, which in turn receive the sensory responses.[11–13]

Biologic integration of dental implants has been extensively studied, but there is a paucity of literature regarding functional integration. This study evaluates the differences in the active tactile perception,

[1]Graduate Student, Department of Periodontics and Implantology, SDM College of Dental Sciences & Hospital, Dharwad - 580009, India.
[2]Professor and Dean, SDM College of Dental Sciences & Hospital, Dharwad, India.
[3]Professor and Head of the Department, Department of Implantology, SDM College of Dental Sciences & Hospital, Dharwad, India.

Correspondence to: Dr Sudhindra Kulkarni, Department of Implantology, SDM College of Dental Sciences & Hospital, Dharwad - 580009, India. Email: drsudhindrak@gmail.com

ie, the interocclusal detection of small objects[10] by implant-supported dental prostheses and natural teeth. Also, to the best of the authors' knowledge, there is no clinical study investigating the changes in the active tactile perception around implants after loading. Hence, the purpose of this study was to evaluate the perception by implants over a period of 6 months after loading in comparison to the natural dentition.

MATERIALS AND METHODS

This prospective study was conducted after getting approval from the institutional review board of the college hospital. A total of 20 patients with implants supporting a fixed prosthesis were recruited immediately after cementation of the prosthesis. A split-mouth design was applied, in which the side with an implant was considered as the test side and the contralateral side with natural teeth was considered as the control. All the subjects selected for the study were rehabilitated with sand-blasted and acid-etched implants (SLA) following a conventional two-stage protocol. The implants were restored with prostheses procured from the same laboratory incorporating an implant-protected occlusal scheme. The prosthesis was cemented with prior occlusal adjustments using a 10-micron articulating paper by the same dentist. The subjects were recruited if they were willing to visit the department for follow-up and fulfilled the following criteria:

- Presence of natural teeth in occlusion on the contralateral side
- Absence of caries/periodontal disease/restoration/ prosthesis on the natural teeth
- Healthy peri-implant tissues
- Absence of underlying neurologic disorders, temporomandibular joint disorders, and bruxism

The subjects were divided into two groups as follows: group 1—subjects with a posterior implant-supported dental prosthesis opposing a healthy natural tooth; and group 2—subjects with posterior implant-supported dental prostheses opposing implant-supported dental prostheses.

The active tactile perception by dental implants was evaluated using a psychophysical test as described by Reveredo et al.[14] Articulating papers (Bausch, Arti-Check) of 8-, 12-, 40-, 60-, and 100-μm thickness were used as test material to determine the occlusal thickness perception.

Method of Test

The subjects received an explanation of the procedure and were oriented to the study design. The subjects were seated comfortably on a dental chair in an upright position and blindfolded. A random order of 50 insertions was determined comprising five true and five false insertions of each articulating paper. The articulating papers were cut into uniform dimensions of 5 × 5 mm. Each test paper was connected to the paper holder and placed on the occlusal surface covering the functional cusp. The patient was then instructed to occlude in maximum intercuspation position. After every test, the subjects indicated if they had felt the paper by raising their hand. A total of 50 insertions, 25 true and 25 false insertions, were performed in the predetermined order, separately for the test (implant) and the control side (natural teeth). During false insertions, the paper holder was placed in the oral cavity without any articulating paper. The response of the patient for every insertion was noted. The perception for a particular paper was considered as positive if it could be detected for ≥ 50% of insertions.

The entire procedure was repeated at the following intervals: 1 week, 3 months, and 6 months post-cementation. The minimum thickness perceived by the patient at each visit was calculated and used for statistical analysis.

Statistical Analysis

Descriptive statistics were performed. The normality test revealed that a majority of the variables did not follow a normal distribution pattern, and hence, nonparametric tests were performed for statistical analysis. The Wilcoxon signed rank test was used to compare the changes in the perception after loading. The Mann-Whitney *U* test was employed for comparison between independent groups. $P < .05$ was considered as the critical *P* value. A Bonferroni correction was applied since multiple comparisons were being made using the Wilcoxon signed rank test. A corrected *P* value (< .008) was used for statistical comparisons when Wilcoxon signed rank test was employed. All data were analyzed using the statistical software (SPSS 20.0).

RESULTS

A total of 20 subjects were included in this study, and all completed the follow-up. The study population comprised 9 men and 11 women with a mean age of 46.2 years. None of the subjects had any complications such as infection, peri-implant bone loss, fracture of the implant/abutment/prosthesis or loosening of the prosthesis/abutment over the duration of the study.

False Positive Response

In group 1, 1/10 subjects elicited a false positive response at the test site. The frequency of false positive

Table 1 Minimum Interocclusal Thickness Detected by Test and Control Sites					
	Test site (μm)				Control (natural teeth) (μm)
	Baseline	1 wk	3 mo	6 mo	
Group 1	53	53	40	30	19
Group 2	80	80	44	31	8

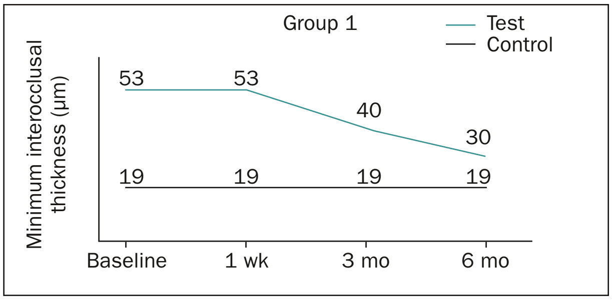

Fig 1a Progressive decrease in the minimum interocclusal thickness detected at the test sites in group 1.

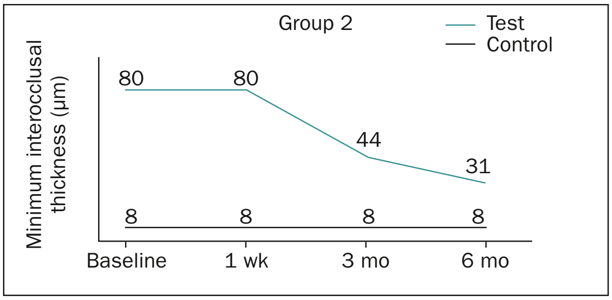

Fig 1b Progressive decrease in the minimum interocclusal thickness detected at the test sites in group 2.

Table 2 Comparison of Interocclusal Thickness Detected at Test Sites During the Follow-up Period by Wilcoxon Signed Rank Test

		Baseline vs 1 wk	Baseline vs 3 mo	Baseline vs 6 mo	1 wk vs 3 mo	1 wk vs 6 mo	3 mos vs 6 mo
Group 1	*P* value	1.00	.10	.04	.10	.04	.10
Group 2	*P* value	1.00	.02	.02	.02	.02	.07

Table 3 Comparison of Interocclusal Thickness Detected by the Test and Control Sites by Mann-Whitney *U* Test

Test > Control	Group 1 *P* value	Group 2 *P* value
Baseline	.02	.00
1 wk	.02	.00
3 mo	.11	.002
6 mo	.26	.002

responses for that subject was 8% (2 out of 25 false insertions) at baseline, which decreased to 0% at the follow-up visits. In group 2, 4/10 subjects elicited a false positive response at the test site. The frequency of false positive responses for the subjects was 40%, 36%, 80%, and 80%, respectively, at baseline, which decreased to 0% at the 1-week follow-up visits.

Minimum Interocclusal Thickness: Changes During the Follow-up Period

In group 1, the minimum occlusal thickness detected by the subjects at the test site was 53 ± 28 μm, which decreased to 30 ± 19 μm over a period of 6 months. The minimum thickness detected by the subjects at the control site was 19 ± 15 μm, which remained the same at all points of evaluation (Table 1 and Fig 1a). The minimum thickness detected at the test site at 3 and 6 months, respectively, was lower than the baseline and 1-week post-cementation values. However, the difference was not statistically significant (Wilcoxon signed rank test, $P > .008$; Table 2).

In group 2 subjects, the minimum thickness detected at the test site at the baseline was 80 ± 28 μm, which decreased to 31 ± 23 μm over a period of 6 months. The minimum thickness detected by the subjects at the control site was 8 μm, which remained the same at all points of evaluation (Table 1 and Fig 1b). The minimum thickness detected at the test site at 6 months and 3 months was lower than the baseline and 1-week post-cementation values; however, the difference was not statistically significant (Wilcoxon signed rank test, $P > .008$; Table 2).

Minimum Interocclusal Thickness: Comparison with Natural Teeth

In group 1, the minimum thickness detected was significantly higher than the control sites at baseline and 1 week (Mann-Whitney *U* test, $P < .05$; Table 3). However, no statistical difference was found between the thickness detected at the test and control sites at the 3-month and 6-month follow-up visits (Mann-Whitney *U* test, $P > .05$; Table 3).

However, in group 2, the minimum thickness detected by the test sites was significantly higher than the control sites at baseline, 1 week, 3 months, and 6 months after loading (Mann-Whitney *U* test, $P < .05$; Table 3).

DISCUSSION

The concept of osseointegration has been proven and accepted widely in literature; it has supported dental implant therapy as it is practiced today. However, whether these dental implants in function perceive tactile sensation is not widely studied. The tactile perception by implants is essential to facilitate a more natural functioning of the implant-supported prosthesis by restoration of the peripheral feedback mechanisms.[1]

Active tactile perception is the "interocclusal detection of small objects," whereas passive tactile perception is the "ability to differentiate between intensities of forces applied to a tooth."[10] Active tactile perception facilitates day-to-day masticatory function and has thus been preferred over passive tactile perception for evaluation.[5,15]

Active tactile perception is affected by age and sex,[5,6,16] implant surface characteristics,[15] time of implantation and loading protocol,[17] occlusal anatomy, and occlusion of the prosthesis.[15] Hence, to rule out the effect of the aforementioned factors, the study population comprised an equal number of men and women; all subjects belonged to the age group of 35 to 50 years; all implants had the same surface characteristics; all implants were placed following the same protocol; all prostheses were obtained from the same laboratory incorporating the implant-protected occlusal scheme; and all prostheses were cemented following occlusal adjustments using 10-μm paper.

A split-mouth design was adopted to facilitate intraindividual comparisons, as the interindividual active tactile sensibility of natural teeth varies widely.[5] Posterior implants were selected as the site for evaluation because they would facilitate precise interposition of the papers and due to their functional importance. To eliminate the psychologic influences, all the subjects were blindfolded,[5,6,15,16] and the test papers were placed in a predetermined random sequence, which included false insertions.[6] Additionally, the articulating papers were cut into uniform dimensions of 5 × 5 mm to avoid soft tissue contact, as it has been observed that the soft tissue contact may influence the perception by implants.[3]

The results of the present study showed that most of the implant-supported prostheses could detect a certain thickness of articulating paper even at baseline, ie, on the day of cementation. Additionally, there was an improvement in the interocclusal thickness perception by the implant-supported prosthesis during the follow-up period. In subjects with implants opposing natural teeth, the tactile threshold decreased from 53 μm to 30 μm, whereas in subjects with implants in opposing arches, it decreased from 80 μm to 31 μm over a period of 6 months. Additionally, the frequency of false positive responses became nil at the follow-up visits.

The interocclusal thickness perception by subjects with implants opposing natural teeth was similar to the natural teeth at the end of follow-up. The results are similar to the study conducted by Enkling et al.[5] However, Reveredo et al (24 vs 12 μm)[14] and Kazemi et al (30 vs 21.4 μm)[16] found that the perception by implant-supported prostheses opposing natural teeth was weaker than by natural teeth.

The interocclusal thickness perception by implant-supported prostheses in both arches was poorer than the control side (natural teeth in occlusion) at the end of the follow-up period. These results were similar to those reported by Lundqvist and Haraldson,[3] Jacobs and van Steenberghe,[4] and Jang and Kim,[18] whereas the study by Batista et al[6] concluded that the perception by implant-supported fixed prostheses in both of the arches was similar to natural teeth. However, unlike the present study, where a split-mouth design was incorporated to facilitate intraindividual differences, the aforementioned studies considered interindividual differences. Hence, direct comparisons are not plausible.

In addition to clinical studies, numerous histologic, neurophysiologic, and functional magnetic resonance imaging (fMRI) studies have reported the phenomenon of osseoperception. Histologic studies have provided evidence that nerve endings exist in the peri-implant bone, which in turn receive the sensory responses.[11–13] Zhu et al[19] and Qiao et al[20] also confirmed the existence of functional neuroreceptors in the peri-implant bone in their histologic and neurophysiologic investigations. Wada et al, in their histologic study, found that loading by occlusal force causes an increase in the number of neurofilament protein (NFP)-positive nerve fibers.[12] Additionally, an fMRI study on patients restored with dental implants showed that mechanical stimulation of the implants activates the corresponding somatosensory cortical areas of the brain.[21] The progressive increase in the tactile sensation seen in the present study can thus be attributed to the development of the NFP positive neural fibers in the peri-implant region in response to loading[12] and cortical adaptation.[21]

To date, only one study by El-Sheikh et al[22] has evaluated changes in passive tactile sensibility during a period of 3 months following implant placement and loading. They found that there was a significant increase in passive tactile sensibility during the healing phase following implant placement. To the best of the authors' knowledge, this is the first study that has evaluated the changes in active tactile perception in osseointegrated dental implants supporting a fixed prosthesis in function. Further studies with a larger sample size evaluating neurophysiologic response are necessary to clarify the findings of the present study.

CONCLUSIONS

Active tactile perception by dental implants in function showed slight improvement over time. At the end of the follow-up period, the active tactile perception by dental implants opposing natural teeth was similar to the natural teeth, whereas it was significantly less in subjects with implant-supported prostheses in opposing arches.

Thus, this study highlights the fact that implants may have a tactile perception of their own. However, further research with a large sample size using neurophysiologic methods should be conducted to confirm the findings of this study.

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