Review Article

DOI: 10.7860/JCDR/2015/14349.6532

Dentistry Section

Osseoperception: An Implant Mediated Sensory Motor Control- A Review

VISHRUT MOHAN BHATNAGAR[1], JYOTI T. KARANI[2], ANSHUL KHANNA[3], PRAVEEN BADWAIK[4], ASHUTOSH PAI[5]

ABSTRACT

Osseointegration of dental implants has been researched extensively, covering various aspects such as bone apposition, biomechanics and microbiology etc however, physiologic integration of implants and the associated prosthesis in the body has received very little attention. This integration is due to the development of a special sensory ability, which is able to restore peripheral sensory feedback mechanism. The underlying mechanism of this so-called 'osseoperception' phenomenon remains a matter of debate. The following article reveals the histological, neurophysiologic and psychophysical aspects of osseoperception. A comprehensive research to provide scientific evidence of osseoperception was carried out using various online resources such as Pubmed, Google scholar etc to retrieve studies published between 1985 to 2014 using the following keywords: "osseoperception", "mechanoreceptors", "tactile sensibility". Published data suggests that a peripheral feedback pathway can be restored with osseointegrated implants. This implant-mediated sensory-motor control may have important clinical implications in the normal functioning of the implant supported prosthesis.

Keywords: Implant prosthesis, Mastication, Osseointegration

INTRODUCTION

The relationship between maxillary and mandibular teeth in different functions is monitored primarily by mechanoreceptors in the periodontal ligament (PDL). Stimulation of the afferent sensory impulses relays information to synapses and the central nervous system, resulting in an efferent response and the initiation of muscular activity. When a patient loses one or more teeth, there is loss of function, impaired aesthetics, and loss of the PDL and its mechano receptors [1]. A common treatment option of removable prosthesis is inherently unstable during functional jaw movements. As a consequence, mastication becomes difficult, sometimes painful, and diet and nutrition suffer. Osseointegrated implants provide alternative treatment options for such patients with better functional integration due to certain tactile sensitivity called osseoperception. A comprehensive research to provide scientific evidence of osseoperception was carried out using various online resources such as Pubmed, Google scholar etc to retrieve studies published between 1985 to 2014 using the following keywords: "osseoperception", "mechanoreceptors", "tactile sensibility".

CONCEPT OF OSSEOPERCEPTION

Osseoperception is defined as mechanoreception in the absence of a functional periodontal mechanoreceptive input and it is derived from TMJ, muscle, cutaneous, mucosal, periosteal mechanoreceptors which provide mechanosensory information for oral kinaesthetic sensibility in relation to the jaw function and the contacts of artificial teeth [2,3].

It is not clear how the neurophysiological mechanisms that modulate jaw movement are associated with the sensory structures around the osseointegrated dental implants [4]. Based on neural inputs, associated with jaw movements, various theories have been put forth by different authors. These theories are beneficial to understand the implant-mediated osseoperception. [Table/Fig-1] [2,5-8].

POTENTIAL MECHANORECEPTORS CONTRIBUTING TO OSSEOPERCEPTION

(a) Joint Mechanoreceptors

Low-threshold mechanoreceptors are present in the TMJs, these receptors in humans play a protective role and also has a limited role in signaling movements and positions of joints [9].

Linden RWA, Scott BJJ in 1989 [5]	Periodontal receptors remain within the bone after extraction [5].
Bonte B et al., in 1993 [6]	Suggest reinnervation in association with controlled forces directed to implants [6].
Klineberg I, Murray G in1999 [2]	Suggests that tempromandibular joint receptors substitute for periodontal ligament receptors of natural teeth [2].
Van Steenberghe D in 2000 [7]	Suggests that periosteum may be the source of proprioceptive responses [7].
Weiner S et al., in 2004 [8]	Suggests that bone adjacent to implants contain nerve fibers [8].

[Table/Fig-1]: Theories of Osseoperception

(b) Muscle Mechanoreceptors

The principal mechanoreceptors associated with muscle are GTOs. Golgi tendon organs are found at the musculo-tendinous junction in series with a small number of extra fusal muscle fibers, and the pull of the muscle fibers with muscle contraction activates GTOs. Golgi tendon organs associated with jaw muscles play an important role in regulating muscle contraction and signaling intramuscular tension. These receptors, together with corollary discharge, are likely to make important contributions to the sense of intramuscular tension generated during voluntary contractions such as biting [10].

(c) Mucosal Mechanoreceptors

Where natural teeth are present, periodontal mechano receptors are important for refined interdental discriminative function. With implant-supported prostheses opposing complete dentures, a contribution to oral kinaesthetic perception could come from the activation of mucosal receptors beneath the prosthesis [11].

In the oral mucosa, different types of mechanoreceptors can be identified including Meissner's corpuscules, glomerular endings, Merkel cells, Ruffini-like endings, and free nerve endings [2].

(d) Periosteal Mechanoreceptors

The periosteum contains free nerve endings, complex unencapsulated and encapsulated endings. The free nerve endings are activated by pressure or stretching of the periosteum through the action of masticatory muscles and the skin [2]. When applying forces to osseointegrated implants in the jaw bone, it might be assumed that the pressure build-up in the bone is sometimes large enough to allow deformation of the bone and its surrounding periosteum [12].

ROLE OF PERI-IMPLANT BONE INNERVATION IN THE OSSEOPERCEPTION

Physiological integration of osseointegrated implants indicates the presence of peri-implant innervations influencing the oral function. However, while reviewing the literature, it can be concluded that the role of this innervation remains only partially understood. Various animal studies have investigated the changes in bone innervation patterns associated with implant placement [13,14]. The presence of nerve fibres involved in bone remodelling and growth at the interface between living and necrotic bone tissue has shown that nerve fibres can regenerate after implant placement. Livia dos Santos Corpas et al., in 2014 described peri-implant nerve fibres around osseointegrated implants in humans [15]. Both myelinated and unmyelinated nerve fibres could be identified inside the Haversian canals of the osteonal bone near the implant threads. Myelinated fibres were also located at the woven bone around the implant. However, no differentiated nerve endings could be observed around the implants. This study shows the presence of nerve fibres in human peri-implant bone, therefore the role of peri-implant bone innervation in the osseoperception phenomenon cannot be ruled out.

HISTOLOGICAL BACKGROUND

Tooth extraction results in reduction of myelinated fibre content of inferior alveolar nerve by 20%. Histological findings indicate that fibers originally innervating the tooth and periodontal ligament are still present in the inferior alveolar nerve [12]. Linden and Scott [5] succeeded to stimulate nerves of periodontal origin in healed extractions sockets, which implies that some nerve endings remain functional.

Histological studies revealed the presence of specialized Ruffini mechano receptive terminals in the immediate vicinity of the implants and in the peri-implant epithelium, which were predominantly derived from myelinated fibers. Moreover, researchers identified abundant unmyelinated nerve fibers under the implant thread area, with implant loading increasing the number of free nerve endings [16].

Wada S et al., in 2001 observed sprouting of new fibers around osseointegrated implants and also the number of free nerve endings close to the bone-to implant interface gradually increases during the first weeks of healing [17]. Whether such regeneration might also induce restoration of the peripheral feedback pathway has however not been studied.

TACTILE FUNCTION OF ORAL IMPLANTS

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. 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 (mm). Studying passive tactile sensibility only allows testing individual neural receptors, whereas, active tactile sensibility more effectively represents normal function and is therefore more interesting for practical dentistry [18].

Linards Grieznis et al., in 2010 compared the passive tactile sensibility of natural teeth with that of osseointegrated dental implants in the maxilla. It was concluded that osseointegrated implants subjectively feel ”touch” sensation when greater force is applied compared with natural teeth [4] [Table/Fig-2]. This was in accordance with the previous published data [19,20].

Enkling et al., in 2010 investigated the active tactile sensibility (ATS) of single tooth implants. The mean value of 20.2 ± 10.9 µm was observed in the study [21]. Mahmoud Kazemi in 2014 compared the active tactile sensibility of implants with that of teeth. He concluded that Average ATS values for teeth and implants were 21.4 um and 30 um, respectively [22], which confirmed the findings of the previously published literature [Table/Fig-3] [21-29].

Compared with the tactile function of natural dentitions, Lundqvist and Haraldson [26] have shown that the active threshold is two to three times higher for implants and the active threshold for implants is 50 times higher than that of natural teeth [20].

Dental status	Passive tactile sensibility (N)
Vital Tooth	0.3
Non – Vital Tooth	0.3
Implant supported Prosthesis	15

[Table/Fig-2]: Passive tactile sensibility of natural teeth and implant supported prosthesis

STUDY	Year	Mean Active Tactile Sensibility (um)
Fenton and Lundqvist [23]	1981	15
Tzakis et al [24]	1990	70
Jacobs and Van Steenberghe [25]	1991	48
Lundqvist and Haraldson [26]	1992	20
Mericske-Stem et al [27]	1995	10
Batista et al [28]	2008	10
Enkling et al [21]	2010	20.2
Reveredo Am et al [29]	2013	24
Mahmoud Kazemi et al [22]	2014	30

[Table/Fig-3]: Findings in the literature regarding active tactile sensibility of implants

The large discrepancies between active and passive thresholds can be explained by the fact that several receptor groups may respond to active testing, while the passive methods electively activate periodontal ligament receptors. The latter are eliminated after extraction, which may explain the reduced tactile function in edentulous patients. After rehabilitation with a bone-anchored prosthesis however, edentulous patients seem to function quite well. These patients perceive mechanical stimuli exerted on osseointegrated implants in the jawbone. If subjects are followed up after implant placement, there is a noticeable improvement in tactile function with oral implants following a 3-months healing period. This special sensory awareness with the bone-anchored prosthesis is osseoperception [12].

However, Judith et al., have shown that patients with implant-supported prostheses appeared to be well adapted to perform habitual masticatory functions. But, during a nonhabitual function such as maximal occluding force, the data revealed a less coordinated masticatory muscle activity in the implant patients [1].

CLINICAL IMPLICATIONS

The concept of osseoperception can help us to restore the habitual masticatory physiologic function with ossointegrated implant supported prostheses, despite the absence of periodontal mechano receptors which are an important component of neuromuscular coordination. However, an abnormal muscle reaction can be induced if eccentric function is not managed leading to implant failures.

CONCLUSION

Endosseous implants are routinely used to rehabilitate amputations of limbs or teeth. In order to reach satisfactory clinical function with such bone-anchored prostheses, physiological as well as psychological integration of the implant(s) should take place. Clinical observations on patients with oral implants indicate the presence of sensory perception after some time. The underlying mechanism of this so-called ‘osseoperception’phenomenon remains a matter of debate.

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PARTICULARS OF CONTRIBUTORS:
1. Lecturer, Department of Prosthodontics, Terna Dental College and Hospital, Maharashtra, India.
2. Professor and HOD, Department of Prosthodontics, Terna Dental College and Hospital, Maharashtra, India.
3. Reader, Department of Prosthodontics, Terna Dental College and Hospital, Maharashtra, India.
4. Reader, Department of Prosthodontics, Terna Dental College and Hospital, Maharashtra, India.
5. Lecturer, Department of Prosthodontics, Terna Dental College and Hospital, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Vishrut Mohan Bhatnagar,
308/B Om Neelkanth C.H.S, Plot no 31, Sector 42 A, Seawoods Nerul West Navi-Mumbai, Maharashtra- 400706, India.
E-mail: vishrutbhatnagar@outlook.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: Apr 06, 2015
Date of Peer Review: Jun 14, 2015
Date of Acceptance: Jun 23, 2015
Date of Publishing: Sep 01, 2015