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Influenza della perdita del legamento periodontale sulla funzione motoria mandibolare e ruolo della osseoperception nella riabilitazione e nel recupero.

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Summary

Abstract

Background: The rehabilitation of the jaw motor control means also the understanding mechanisms previuos it (periodontal ligament loss), when it's necessary and what role have the osseoperception phenomenon in this field.

Aim: Understanding the role of periodontal ligament in the motor control, the consequences after extraction/loss of dental elements in the jaw motor control and the role of osseoperception and the importance of a setting methodology for assessment and rehabilitation of the motor control function based on a visual feedback.

Methods: This narrative review is made following PRISMA statement suggestions. An electronic search was done on the Pubmed website, using mesh terms and key words: 1)periodontal ligament and motor control; 2) periodontal mechanoreceptor and motor control; 3)dental implant and osseoperception; 4) bite force and motor control and visual feedback. Eligibility Criteria included both animal and human studies; no time or age limits are used. All the articles selected for the review are in English and, with available full text. Review articles are excluded and are used only for writing the background.

Results: The loss of periodontal ligament create an alteration of the oral motor behavior and the rehabilitation, supported by visual-feedback, with the help of osseoperception, seems to be the best practice.

Conclusions: the studies were of low quality, but they were almost all analytical. From their analysis results that the rehabilitation of motor control, essential when the impairment or absence of sensory signaling from PMRs caused in subjects altered behavior, remain a field to develop.

1. **Introduction**

Oral motor behaviors (such as biting, chewing, speech ecc.) are controlled by the brain that receives information from sense organs in the orofacial structures. Natural teeth are equipped with extremely sensitive tactile sensors – mechanoreceptors in the periodontal ligament (Pdl). These sensors provide information about tooth loads and are located among the collagen fibers in the ligaments that attach the root of the tooth to the alveolar bone(1).

The loss of one or more teeth means the loss of Pdl and its mechanoreceptors (2). Extraction of teeth is similar to an amputation of a limb; indeed, in both cases, an important part of the peripheral feedback pathways is destroyed and socket prosthetic limbs or denture don't carry enough potential to restore the sensory feedback pathways. It has been assumed that by anchoring prosthetic limbs directly to the bone via osseointegrated implants, partial sensory substitution can be realized: it seems that an activation of the receptors in the neighbourhood might be the responsible for restoring pathways (3, 4). This special sensory awareness with the bone-anchored prosthesis is called Osseoperception.

This phenomenon is defined as the sensation arising from mechanical stimulation of a bone anchored prosthesis, transduced by mechanoreceptors that may include those located in muscle, joint, mucosal, cutaneous and periosteal tissues; together with a change in central neural processing in maintaining sensorimotor function (5).

Despite, it has been shown that patients with implant-supported prostheses appeared to be well adapted to perform habitual masticatory functions, a less coordinated masticatory muscle activity implants patients is revealed, compared to natural dentition(2).

Moreover, some trials specified the threshold of tactile sensitivity and, consequently, the masticatory load with dental implants to be 8 – to 10 – fold higher than with natural teeth(6) (7) .

Investigating food holding and biting behaviour, a marked disturbance in control of precisely directed and low biting forces has been demonstrated, and it has been suggested that the receptors play a significant role in the specification of the level, direction, and point of attack of forces used to hold and manipulate food between the

anterior teeth (8).

The aims of this review are understanding the role of periodontal ligament in the motor control, Consequences after extraction/loss of dental elements in the jaw motor control and discussing the role of osseoperception and the importance of a setting methodology for assessment and rehabilitation of the motor control function based on a visual feedback.

2. Materials and Methods

2.1 Objectives

Reviewing the literature regarding the influence of periodontal ligament loss on the jaw motor control and the role of osseoperception in oral rehabilitation and motor control. Question raised and discussed in this review are:

- Periodontal ligament afferents role in motor control mechanism
- Consequences on jaw sensory-motor function, after loosing ligament in case of extraction/loss of dental elements and discussing the role of osseoperception
- Explain the importance of a setting methodology for assessment and rehabilitation of the motor control function based on a visual feedback.

2.2 Data source and search strategies

This narrative review is made following PRISMA statement suggestions. An electronic search was done on the Pubmed website, using mesh terms and key words:

1) periodontal ligament and motor control

2) periodontal mechanoreceptor and motor control

3) dental implant and osseoperception

4) bite force and motor control and visual feedback

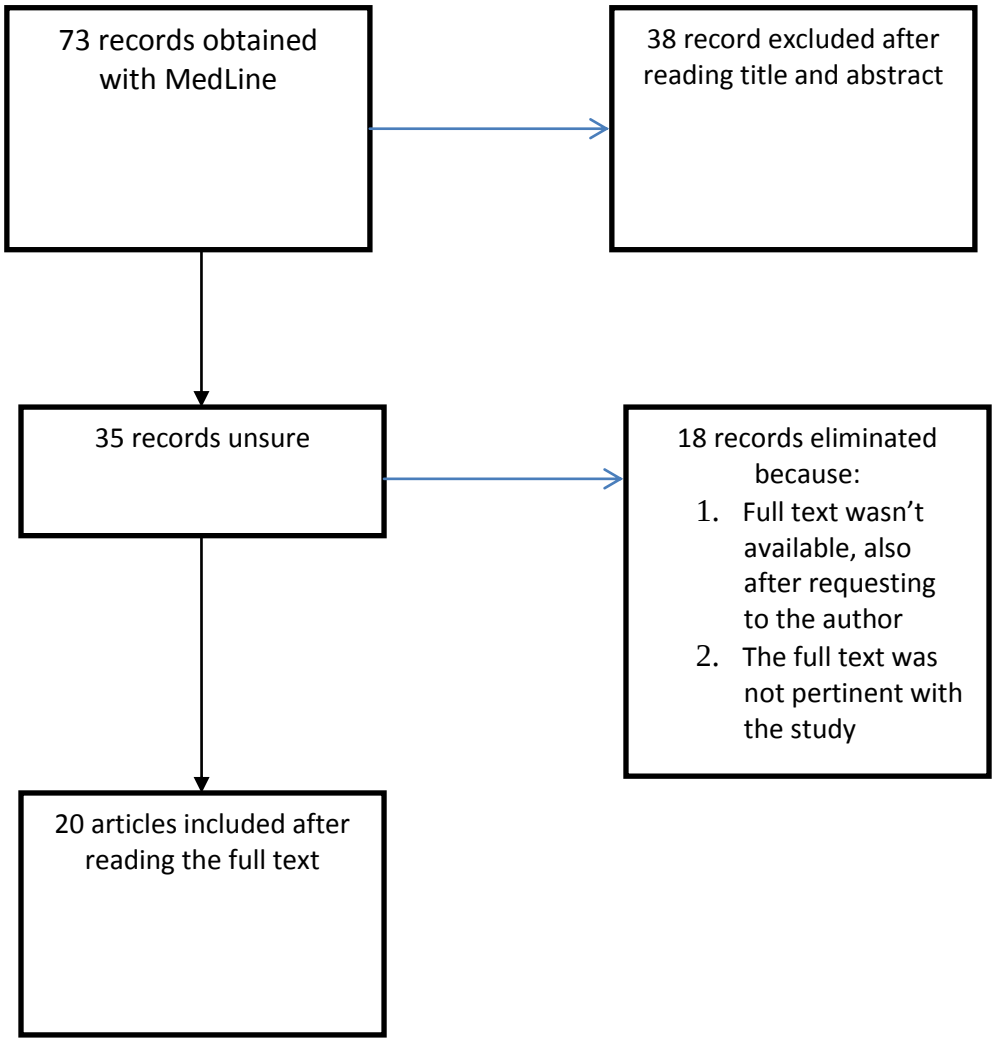
2.3 Inclusion Criteria: Eligibility Criteria included both animal and human studies; no time or age limits are used. All the articles selected for the review are in English and, with available full text.

2.4 Exclusion Criteria

Review articles are excluded and are used only for writing the background.

2.5 Selection process

Selection of the studies was performed by only a reviewer. After reading the abstract, articles non relevant were removed.



2.6 Characteristics of the studies excluded

The study excluded from the review hadn't got full text available, also after requesting to the author or the full text was not pertinent with the study.

2.7 Assessment of risk of bias

It had been examinated items of the reporting for observationals studies, according to STROBE, to evaluate the quality of studies and their limits.

3. Results

Author	Trulsson M, Francis ST, Bowtell R, McGlone F
Title	Brain Activations in Response to Vibrotactile Tooth Stimulation: a Psychophysical and fMRI Study
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	Investigate PDLMs properties, psychophysically and with fMRI, in response to varying frequencies of dynamic (vibrotactile) stimulation, and comparison of responses to tooth stimulation with those produced by identical vibrotactile stimulation of the finger
Summary	10 healthy volunteers were analyzed. Mechanical vibrotactile stimuli were delivered via a probe attached to a piezoelectric bender element stimulator, fixed to a piece of plexiglas, horseshoe shaped, held by teeth, so that the probe just made contact with center of the left upper incisor. To stabilize the piece of plexiglas in the mouth was use a silicon impression to make a mold of the partecipant's teeth. the mechanical stimulus was driven with a sinusoidal waveform generator. The frequency and amplitude of the stimulus was controlled using LabVIEW and digitized displacement signals detected in terms of force. The volunteers were stimulated in supine position in the left incisor during fMRI session, the mechanical stimuli was delivered at 20, 50 and 100 Hz. At no frequency did any subject report any sensations of pain. the stimulus was presented for 9s, follwed by 27s of rest. This ON-OFF procedure was repeated for 30 cycles, 10 cycles at each stimulation frequency were presented in random order.
Outcomes	Mechanical stimulation of the upper left central incisor revealed significant activation of the primary somatosensory and secondary somatosensory cortex, SMA, posterior and anterior insular and parietal regions at low frequency (20 Hz). In addition activation was also found in the anterior operculum (BA 43), motor cortex (BA 6), inferior and medial frontal cortex (BA 45/9), and cerebellum. Activation in the primary and secondary somatosensory cortex was significantly reduced at higher frequencies (50 and 100 Hz).
Limits	The low number of participants. The subjects were instructed to wait the stimulus.

Author	Pascale Habre-Hallage, Laurence Dricot, Reinhilde Jacobs, Daniel van Steenberghe, Hervé Reychler, Cecile B. Grandin
Title	Brain plasticity and cortical correlates of osseoperception revealed by punctate mechanical stimulation of osseointegrated oral implants during fMRI
Type of study	Human study. The design of study was enunced in the abstract: cross-sectional study
Purpose	The aim of the present study was to use a tactile stimulation to identify the cortical adaptive processes that may be associated with the use of oral endosseous implants. To achieve this goal, the cortical projections of periodontal mechanoreceptors were compared with those induced by stimulation of peri-implant tissues in two groups of subjects. In order to understand how humans adapt (or not) to tooth replacement by bone-anchored prostheses and how they might produce their functional rehabilitation effect.
Summary	9 Right-handed volunteers with a complete natural healthy dentition and no other implants in the mouth except for the maxillary left incisor tooth that was missing and replaced by a single crown on an endosseous two-stage implant (Brånemark system) was selected. The implants were loaded for at least 2 years prior to the present fMRI recordings. Ten subjects without any oral implants, served as the control group. Exclusion criteria were pregnancy and the usual MRI contraindications: pacemakers, defibrillator wires, ferromagnetic cerebral aneurysm clips, cochlear implants and metal fragments in the eye. For each patient, functional magnetic resonance imaging (fRMI) recordings were made during punctate mechanical stimulation of 1 Hz of left central incisor, canine tooth or central incisor implant in the maxillary area. A block design paradigm was used to stimulate, in 9 patients, maxillary left central incisor implants (I21-p) and maxillary left canines (T23-p). In 10 control subjects, maxillary left central incisors and canines (T21-c, T23-c) were stimulated. Random effect group analyses were performed for each stimulated site, and differences in cortical activity elicited when loading teeth or implants were examined using ANOVA.
Outcomes	As a group, patients activated somatosensory area S2 bilaterally for both I21 and T23, while controls activated S1 and S2 bilaterally for T21 and T23. At an individual level, S1 was activated by 4/9 implants, mainly on the ipsilateral side. The stimulated implants activated a larger bilateral cortical network outside the somatosensory areas: in parietal, frontal and insular lobes, the main clusters being located in the inferior frontal gyri. Stimulation of T23 in patients resulte in an activation pattern intermediate between that of the implants and that of natural teeth in controls.This study demonstrates that punctate mechanical stimulation of oral implants activates both primary and secondary cortical somatosensory areas. It also suggests that brain plasticity occurs when extracted teeth are replaced by endosseous implants. This cortical activation may represent the underlying mechanism of osseoperception.
Limits	No more subjects should be included with various implanted sites. To better understand the relationship between the activated cortical network and the subjects, the sensory perception, psychophysical measurements of the tactile function of the implant and peri-implant tissues should be correlated to the brain activations. Longitudinal fMRI recordings on human subjects undergoing extraction and subsequent oral implant placement are needed to substantiate the cortical plasticity that the present study suggests.

Author	Zhang Y, Boudreau S, Wang M, Wang K, Sessle B, Arendt-Nielsen, Svensson P.
Title	Effects of periodontal afferent inputs on corticomotor excitability in humans
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cohort study
Purpose	Determine in humans whether local anaesthesia or nociceptive stimulation of the periodontal ligaments affects the excitability of the face primary motor cortex, measured by TMS
Summary	12 healthy volunteers (11 male, 1 female) participated in two 3-h sessions, separated by 7 days. They were randomly injected with LA carbocain or with Nociceptive irritant capsaicin into the periodontal ligament of the lower right central incisor. In each session TMS motor evoked potentials (TMS-MEP) stimulus response curves and corticomotor maps for the tongue, masseter, and first dorsal interosseous (internal control) were constructed before and at 5, 30, and 60 minutes post-application of La or capsaicin. The intensity of burning pain was recorded throughout the duration of each session on an electronic visual analogue scale. The intensity of mechanical sensation produced by application of a von Frey filament, by the investigator, over the gingival sulcus near the injection site was recorded on a VAS before and immediately after the acquisition of each TMS-MEP stimulus-response curve.
Outcomes	A transient loss or perturbation in periodontal afferent input to the brain from a single incisor is insufficient to cause changes in corticomotor excitability of the face MI, as measured by TMS in humans
Limits	A more exttensive blockage of the periodontal afferent input to determine if it would have more robust impact on motor control of jaw and tongue muscles

Author	T. Fujio, F. Sato, Y. Tachibana, T. Kato, A. Tomita, K. Higashiyama, T. Ono, Y. Maeda, A. Yoshida
Title	Revisiting The Supratrigeminal Nucleus In The Rats
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	1) the cytoarchitecture of the rat supratrigeminal region; 2)the location of the identified Vsup in comparison to the location od NADPH-d positive area (trigeminal transition zone); 3) which primary afferents terminate in the rat Vsup by means of transglionic tracer application to six primary afferents; 4) whether neurons in the cytoarchitectonally identified Vsup respond to the electrical stimulation of Vmes afferents.
Summary	50 male wistar rats ranging in weight from 230 to 330 g, anesthetized, monitoring temperature and ecg, in five rats were tested the deep temporal nerve, in eight the masseter nerve, in six the medial pterygoid nerve and in other eight the inferior alveolar nerve applying the tracer to the nerves. For the tracer application in the infraorbital nerve we made two groups of six and three rats. At least for the lingual nerve five rats. For electrophysiological study in six rats, the masseter nerves were dissected and silver bipolar electrodes were attached to the nerve. The potentials were stored on a computer. All the animals where re-anesthetized after 5-7 days in case of CTb applications or after 14-20 days in case of BDA application or soon after HRP injections. Moreover, they and other three rats were perfused with the paraformaleide, and then the mesencenphalon and the pons were removed and freezing, to be cutting in sections after 3-4 days.
Outcomes	1)identification of the rat Vsup is an independent area surrounded laterally by the dorsomedial part of the trigeminal principal sensory nucleus, medially by the trigeminal mesencephalic tract, dorsally by the ventromedial part of the parabrachial nucleus and ventrally by the Vmo; 2)No NADPH-d positive neurons were found in the region, but they were found in the Vor; 3)The rat Vsup receives remarkable termination of Vmes primary afferents innervating the jaw closing muscle spindles ; 4) Neurons in the cytoarchitectonally identified Vsup respond to the electrical stimulation of Vmes afferents.
Limits	Cytoarchitectonic of Vsup of rats, but nowadays it's not possible to study in humans.

Author	Takuya Asano, Jorge L Zeredo, Toda, Kunimichi Soma
Title	Periodontal Masseteric Reflex is Changed by Periodontal Sensory Modification during Occlusal Hypofunction in Rats
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cohort study
Purpose	Investigate changes in the periodontal masseteric reflex after experimentally induced occlusal hypofunction in rat in vivo.
Summary	60 female wistar albino rats (randomly split into control group and hypofunction group and every groups was further divided into 5 five groups). Lower incisors on both sides were cut in animals of hypofunction group and electrical stimulation of periodontal ligament or MEV was given to both groups recording results at o, 1, 2, 4, and 6 weeks.
Outcomes	After stimulation of the pdl the latency of masseteric motor unit responses in 4 and 6w- Hgs was increased as compared to Cgs, while the electrical stimulation to the Mev, no significance differences in the latencies were found between the two groups. The thresholds of the masseteric unit responses significantly increased in the 4 and 6w- Hgs as compared to Cgs. Results suggest that occlusal hypofunction induced changes in the threshold latency of the PMR might greatly affect the coordination of mastication. Occlusal hypofunction might cause modification in periodontal sensory function.
Limits	Animal study, a longer experimental period could change the latency, that in this experiment was similar in both groups at any week.

Author	Abhishek Kumar, Mats Trulsson, Krister G. Svensson, Flemming Isidor, Lene Baad-Hansen, Peter Svensson
Title	Optimization of jaw muscle activity and fine motor control during repeated biting tasks
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cohort study
Purpose	Investigate if repeated holding and splitting food morsel change the variability of force and jaw muscle activity in participants with natural dentition
Summary	Twenty healthy volunteers participated in a single session divided into six series. Each series consisted of ten trials of a standardized behavioral task (total 60 trials) involving holding and splitting a flat-faced tablet placed on a bite force transducer with the anterior teeth. The hold and split forces along with the electromyographic (EMG) activity of the left and right masseter (MAL and MAR), left anterior temporalis (TAL) and digastric (DIG) muscles were recorded.
Outcomes	No evident optimization of jaw motor function in terms of reduction in the variability of bite force values and muscle activity, when this simple task was repeated up to sixty times in participants with normal intact periodontium.
Limits	Study a more extensive training, with imaging studies, if it would have a robust impact on jaw motor control and also whether this training could help patients after oral rehabilitation

Author	P.F. Sowman, K.S. Türker
Title	Periodontal-Masseteric Reflexes Decrease with Tooth Pre-load
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	1)Investigate the masseteric reflex response to periodontal mechanoreceptor stimulation under conditions of various tooth pre-loads. 2)the entrainment of the periodontal-masseteric reflex would be strongest at a frequency that best matched the known mean firing rate of masseteric motoneurones, i.e., ~ 20 Hz.
Summary	In 10 participants, central incisor repeatedly tapped. They measured the modulation by pre-load of the reflex frequency-response at and between 3 and 20 Hz. . After injection of LA, the stimulation conditions were repeated
Outcomes	This study showed that the action of periodontal mechanoreceptors can reflexively alter bite-force during biting tasks only where the force exerted is small. This was evidenced by the sharp decline in evocable reflex activity when the tooth was pre-loaded above 1 N. The PMR and tooth pre-load agreed with the load response. Hence, periodontal mechano-receptors are able to contribute to the ongoing control of only small bite-forces
Limits	Small sample

Author	L dos Santos Corpas, I Lambrichts, M Quirynen, B Collaert, C Politis, L Vrielinck, W Martens, T Struys, R Jacobs
Title	Peri-implant bone innervation: Histological findings in humans
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	Describe nerve fibres around osseointegrated implants in humans
Summary	Twelve mechanically failed implants, retrieved from 10 patients were collected from three dental centres over a period of 5 years After implant removal, decalcified semi-thin sections were stained with thionic methylene blue for light microscopic analysis and an ultrastructural analysis was performed on serial ultra-thin sections using transmission electron microscopy.
Outcomes	Presence of nerve fibres, both myelinated and unmyelinated, in human peri-implant bone but no differentiated nerve endings could be observed.
Limits	A bigger sample of failed implants

Author	Pascale Habre-Hallage, Nada Bou Abboud-Naaman, Herve Reychler, Daniel van Steenberghe, Reinhilde Jacobs
Title	Perceptual Changes in the Peri-Implant Soft Tissues Assessed by Directional Cutaneous Kinaesthesia and Graphaesthesia: A Prospective Study
Type of study	Human study. The design of study was enunced in the title: cohort study
Purpose	Compare the perception of mechanical stimuli applied to the buccal mucosa in the vicinity of osseointegrated oral implants with that in the controlateral dentate side
Summary	17 subjects with 20 implants. Directional cutaneous kinaesthesia (DCK) and graphesthesia (G) were performed on the buccal side of the alveolar mucosa before and at planned intervals after implant placement. Observation pursued until 6 month after the prosthetic rehabilitation. Contralateral mucosa served as a control to the implant sites
Outcomes	Tooth loss reduces tactile function compared with implant-supported prostheses. Peri-implant soft tissues could be partially involved in the osseoperception function.
Limits	A bigger sample and longer experiment observations

Author	Norbert Enkling, Stefan Heussner, Claudia Nicolay, Stefan Bayer, Regina Mericske-Stern, Karl-Heinz Utz
Title	Tactile Sensibility of Single-Tooth Implants and Natural Teeth Under Local Anesthesia of the Natural Antagonistic Teeth
Type of study	Human study. The design of the study was enunced in the title: single blind, split-mouth study
Purpose	Clarification of how far tactile sensibility is to be attributed to the periodontium of the natural opposing tooth of the implant
Summary	32 subjects with single-tooth implants with natural opposing teeth After anesthetizying the natural antagonistic tooth of the implant and the corresponding natural contralateral one, copper foils of varying thickness were placed interocclusally between the single-tooth implant and the natural opposing tooth in a randomized way, and between the contralateral pair of natural opposing teeth
Outcomes	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.
Limits	It’s impossible standardize the dynamic forces in the mouth. They evaluated the minimum thickness detectable on only one subject who had got the best perception potential. Small sample.

Author	Mahmoud Kazemi, Farideh Geramipanah, Ramin Negahdari, Vahid Rakhshan
Title	Active Tactile Sensibility of Single-Tooth Implants versus Natural Dentition: A Split-Mouth Double-Blind Randomized Clinical Trial
Type of study	Human study. The design of the study was enunced in the title: double blind, split-mouth study
Purpose	Explore the difference between the ATS of teeth and single-tooth implants
Summary	ATS of single-tooth implants and contralateral teeth was measured in 25 patients for five times, in a random order blinded to patients and assessor, carried out at two sessions
Outcomes	Slight but statistically significant difference between implant and tooth tactile sensitivities detected
Limits	It's impossible standardize the dynamic forces in the mouth. They evaluated the minimum thickness detectable on only one subject who had got the best perception potential. Small sample.

Author	Yan Huang, Jeroen van Dessel, Xin Liang, Reinhilde Jacobs
Title	Sensory innervation around immediately vs. delayed loaded implants: a pilot study
Type of study	Animal study. The design of the study was enounced in the title: pilot study, randomized split-mouth trial
Purpose	Histomorphometrically assess the effects of immediate and delayed implant loading on peri-implant innervation
Summary	Six healthy male mongrel dogs, without any oral health or systemic diseases and housed individually in indoor cages. Each implant recipient site was randomly assigned to one of four treatment protocols and a general two-stage implant placement was applied.
Outcomes	This study helped uncover the tendency that the immediately placed and loaded implant group may have an improved peri-implant innervation pattern, including higher nerve density, larger fibre diameter and axon diameter, and more axonal myelination. The current histological findings on these regenerated nerve fibres may expand the concept of osseoperception to more challenging levels and may evolve with osseointegration in the oral environment and in ear–nose–throat and orthopaedics specialties.
Limits	Animal study. Small sample

Author	Yan C, Ye L, Zhen J, Ke L, Gang L.
Title	Neuroplasticity of edentulous patients with implant-supported full dentures
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	Analyze the cortical plasticity occurring in patients with implant-supported prostheses
Summary	20 edentulous patients with implant-supported full dentures or traditional complete dentures were recruited for a clenching task and they were scanned by functional magnetic resonance imaging (fMRI)
Outcomes	Sensory and motor feedback to the central nervous system can be restored by implant-supported full dentures. Activation of the primary sensorimotor cortex in patients with implant-supported dentures might explain the improved tactile, stereognostic ability and mastication functions, which are more similar to the natural dentition.
Limits	Small sample

Author	K. Van Loven, R. Jacobs, A. Swinnen, S. Van Huffel, J. Van Hees, D. van Steenberghe
Title	Sensations and trigeminal somatosensory-evoked potentials elicited by electrical stimulation of endosseous oral implants in humans
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross-sectional study
Purpose	Description of the perceptions arising from the innervation of the intimate bone–implant contact by means of localized electrical stimulation and analysis of TSEPs.
Summary	Fifteen patients aged from 35 to 69 years edentulous in the lower jaw and had received two endosseous titanium implants (Bra˚nemark system)
Outcomes	Topical anesthesia of the gingiva surrounding the implants in six individuals had little effect on the sensory responses. This evidence excluded peri-implant mucosal innervation as the origin of the perception and of the somatosensory-evoked waves elicited by the electrical stimulation of the oral implants For the first time a sensation (osseoperception) has been elicited by electrical stimulation of endosseous oral implants and correlated with simultaneously recorded trigeminal somatosensory-evoked potentials (TSEPs)
Limits	Small sample

Author	Mauro Batista, Wellington Bonachela Janir Soares
Title	Progressive recovery of osseoperception as a function of the combination of implant-supported prostheses
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a case control study
Purpose	Evaluate the recovery of interocclusal sensory perception for micro-thickness in individuals with different types of implant-supported prostheses.
Summary	Wearers of complete dentures (CDs) comprised the negative control group. The experimental group consisted of wearers of prostheses supported by osseointegrated implants, which was divided into 4 subgroups. Individuals with ND represented the positive control group. Aluminum foils measuring 10 mm, 24 mm, 30 mm, 50 mm, 80 mm, and 104 mm thickness were placed within the premolar area, adding up to 120 tests for each individual.
Outcomes	Conventional CDs presented a significant loss of the inter-occlusal tactile threshold for micro-thicknesses. Fixed or removable implant-supported prostheses allowed for the recovery of the interocclusal tactile threshold at levels similar to that of natural teeth. This clinical evidence strengthens the premise of the connection of global neurophysiological integration of the implant to the stomatognathic system.
Limits	Using small sample

Author	Joannis Grigoriadis, Mats Trulsson. Krister G. Svensson
Title	Motor behavior during the first chewing cycle in subjects with fixed tooth- or implant-supported prostheses
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross sectional study
Purpose	Describe motor behavior during the first cycle of a natural chewing task and evaluate the role of such sensory input in this behavior
Summary	10 subjects with natural dentition, 11 with bimaxillary fixed tooth-supported prostheses (TSP) and 10 with bimaxillary fixed implant-supported prostheses (ISP), chewed a total of five hazelnuts, their vertical and lateral jaw movements were recorded. Data obtained during the first chewing cycle of each hazelnut were analyzed.
Outcomes	Subjects with fixed tooth- or implant-supported prostheses in both jaws show altered behavior, including inadequate control of the hazelnut, during the first chewing cycle. These differences are due to impairment or absence of sensory signaling from PMRs in these individuals.
Limits	Small sample

Author	Krister G. Svensson, Joannis Grigoriadis, Mats Trulsson
Title	Alterations in intraoral manipulation and splitting of food by subjects with tooth- or implant-supported fixed prostheses
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross sectional study
Purpose	1)Examine motor behavior during a novel “manipulation-and-split” task, involvingpositioning (with the help of the tongue and lips) a spherical piece of chocolate drage´e candy between the front teeth and thereafter splitting it into two equal-sized parts. 2) Assess the extent to which control of this intraoral motor task is dependent on PMRs signaling by comparing among subjects with natural teeth to others with fixed prostheses supported by natural teeth or dental implants.
Summary	10 subjects with natural teeth, 10 with bimaxillary tooth-supported fixed prostheses (TSP) and 10 with bimaxillary implant-supported fixed prostheses (ISP) performed an intraoral manipulation-and-split task thatinvolved positioning a spherical chocolate drage´e between the front teeth and then splitting it into two parts of equal size. The vertical jaw movement, sound of food cracking and masseter muscle activity were monitored during this task, evaluating accuracy of the split.
Outcomes	Impairment (TSP) or absence (ISP) of the information that originate from PMRs, alters motor behavior and impairs performance during the natural biting task employed here.
Limits	Small sample

Author	M. Trulsson, H.S.J. Gunne
Title	Food Holding and biting behaviour in human subjects lacking periodontal receptors
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross sectional study
Purpose	Periodontal mechanoreceptors is important for the fine motor control of the mandible, i.e., when humans hold and carefully manipulate food particles between the teeth with low biting forces.
Summary	Comparing the performance of three age- and gender-matched groups of 24 subjects, 8 for each group), for which the integrity of the periodontal sensory apparatus differed (natural dentition, complete denture, implant supported prostheses), they split an hal peanut after 3 second on each trial (20 trials per participant). Also the trial when the peanut escaped were recorded.
Outcomes	The results demonstrate a marked disturbance in the control of precisely directed, low biting forces in subjects lacking periodontal receptors and suggest that the receptors play a significant role in the specification of the level, direction, and point of attack of forces used to hold and manipulate food between the anterior teeth. Moreover, other types of mechanoreceptors can not fully compensate for the loss of periodontal receptors. No differences found between the group of complete denture and implant supported prostheses.
Limits	Small sample

Author	Testa, M.Geri, T.Signori, A. Roatta, S.
Title	Visual Feedback of Bilateral Bite Force to Assess Motor Control of the Mandible in Isometric Condition
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cross sectional study
Purpose	Assessment of the individual ability of modulating and coordinating the right and left bite force is poorly investigated and evaluates the test-retest reliability in a sample of 13 healthy subjects.
Summary	By modulating the intensity and the left/right balance of the biting force, the subject was able to drive a cursor on the screen to "reach and hold" targets, randomly generated within the physiological "range of force" of the subject.
Outcomes	This technique improves the characterization of the mandibular motor function and it may have a relevant role for the assessment and rehabilitation of the neuromusculoskeletal disorders affecting the orofacial system.
Limits	A small and healthy subjects sample

Author	Testa M, Rolando M, Roatta S.
Title	Control of jaw clenching in dentate subjects
Type of study	Human study, not indicate the design of the study in the title or abstract. According to the analysis of the article, it's a cohort study
Purpose	To characterize the control of jaw clenching forces by means of a simple force-matching exercise
Summary	17 healthy subjects, provided with a visual feed-back of the exerted force, carried out a unilateral force-matching exercise requiring, developing and maintaining for 7s, a jaw clenching force at 10%, 30%, 50%, 70%of the MVC. The task was repeated two times in each two sessions.
Outcomes	The approach adopted is adequate to assess, individual force control
Limits	A small and healthy subjects sample

4. Discussion

4.1 Periodontal ligament afferents role in motor control mechanism

The first studies (9) investigated changes in the periodontal masseteric reflex after experimentally induced occlusal hypofunction in rat in vivo. The periodontal masseteric reflex is an important reflex that controlled jaw movement. The ascendance of the PMR arc consists of the periodontal mechanoreceptor and the afferent of the PMR, a tip branch of trigeminal mesencephalic nucleus (MeV) neuron distributed over the periodontal ligament. Studies on animals suggested that a functional occlusion is essential, maintaining functional the periodontal mechanoreceptors. Therefore, an occlusal hypofunction was studied in 60 female wistar albino rats (randomly split into control group and hypofunction group and every groups was further divided into 5 five groups). Lower incisors on both sides were cut in animals of hypofunction group and electrical stimulation of periodontal ligament or MEV was given to both groups recording results at o, 1, 2, 4, and 6 weeks. Changes were found in the threshold latency of the PMR and this might greatly affect the coordination of mastication. Occlusal hypofunction might cause modification in periodontal sensory function.

One year later,(10) another author examined the PMR response to periodontal mechanoreceptor stimulation under conditions of various tooth pre-loads. The entrainment of the periodontal-masseteric reflex would be strongest at a frequency that best matched the known mean firing rate of masseteric motoneurones, i.e., ~ 20 Hz.

In 10 participants, central incisor repeatedly tapped. They measured the modulation by pre-load of the reflex frequency-response at and between 3 and 20 Hz. . After injection of LA, the stimulation conditions were repeated. This study showed that the action of periodontal mechanoreceptors can reflexively alter bite-force during biting tasks only where the force exerted is small. This was evidenced by the sharp decline in evocable reflex activity when the tooth was pre-loaded above 1 N. The PMR and tooth pre-load agreed with the load response. Hence, periodontal mechano-receptors are able to contribute to the ongoing control of only small bite-forces.

Recently indeed, was enhanced the cytoarchitecture of the rat supratrigeminal region(11), previously matter of debate (12).

Also the location of the identified Vsup in comparison to the location of NADPH-d

positive area (trigeminal transition zone), which primary afferents terminate in the rat Vsup by means of transglionic tracer application to six primary afferents and whether neurons in the cytoarchitectonally identified Vsup respond to the electrical stimulation of Vmes afferents. 50 rats were analyzed in order to record the potential of the nerve evaluated and to study the cytoarchitecture of the supratrigeminal region. The results suggested that the rat Vsup is an independent area surrounded laterally by the dorsomedial part of the trigeminal principal sensory nucleus, medially by the trigeminal mesencephalic tract, dorsally by the ventromedial part of the parabrachial nucleus and ventrally by the Vmo; No NADPH-d positive neurons were found in the region, but they were found in the Vor; the rat Vsup receives remarkable termination of Vmes primary afferents innervating the jaw closing muscle spindles; neurons in the cytoarchitectonally identified Vsup respond to the electrical stimulation of Vmes afferents.

These studies were conducted on animals, only one in Humans, and they had got short periods of experimental study, but they highlighted the fundamental role of periodontal ligament on the control of oral behaviuor, and his ascendance that are strictly connected to the brain stem.

Also the tactile sensory processing of forces applied to the teeth is important for the perception of mechanical properties of food brought into the mouth and motor control of mastication. Different mechanoreceptor types in the oral tissues and jaw muscles provide information related to tooth load with a central role being played by PDLMs. These Ruffini-like nerve endings are located among the collagen fibers in the pdl. Human periodontal mechanoreceptors adapt slowly to tooth loads and show response properties similar to the slowly adapting type II (SA II) low threshold mechanoreceptor in the skin, the authors investigated PDLMs properties, psychophysically and with fMRI, in response to varying frequencies of dynamic (vibrotactile) stimulation, and comparison of responses to tooth stimulation with those produced by identical vibrotactile stimulation of the finger 10 healthy volunteers were analyzed(13). The volunteers were stimulated in supine position in the left incisor during fMRI session, the mechanical stimuli was delivered at 20, 50 and 100 Hz. At no frequency did any subject report any sensations of pain. The stimulus was presented for 9s, follwed by 27s of rest. This ON-OFF procedure was repeated for 30 cycles, 10 cycles at each

stimulation frequency were presented in random order. Results suggested that mechanical stimulation of the upper left central incisor revealed significant activation of the primary somatosensory and secondary somatosensory cortex, SMA, posterior and anterior insular and parietal regions at low frequency (20 Hz). In addition activation was also found in the anterior operculum (BA 43), motor cortex (BA 6), inferior and medial frontal cortex (BA 45/9), and cerebellum. Activation in the primary and secondary somatosensory cortex was significantly reduced at higher frequencies (50 and 100 Hz). The limits are the low number of participants and that the subjects were instructed to wait the stimulus. An interesting result derived from a study in which a transient loss or perturbation in periodontal afferent input to the brain from a single incisor is insufficient to cause changes in corticomotor excitability of the face MI, as measured by TMS in humans (14) In further studies we could be observed the effects of an extensive blockage on the periodontal afferent input to determine whether it would have more robust impact on motor control of jaw and tongue muscles.

4.2 Consequences on jaw sensory-motor function, after loosing ligament in case of extraction/loss of dental elements and discussing the role of osseoperception

Tooth loss reduces tactile function. 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), while 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. Anyway, the study about passive and active tactile sensibility are contradictory, because in passive tactile studies the implants are clearly less sensitive than the teeth selected for comparison, while in the second the inter-occlusal perception of single tooth implants when occluding against natural antagonist and of remaining natural dentition are equivalent.
When passive tactile perception was tested with and without local infiltration of

anesthesia of the peri-implant tissue and with and without a prosthetic abutment which prevented any contact with the soft tissue, it was shown that the removal of abutment and local anesthesia had no influence on the perception thresholds under static and dynamic loads on the implants. In the case of natural teeth passive tactile perception was significantly worse under soft tissue anesthesia because the anesthesia inactivated the receptors in the mucosa of the natural teeth. Probably the passive tactile capability of implants is probably to be attributed to receptors in the bone rather than to mucosal receptors. The difference between the active and passive perception can be explained by the fact that in the active test, various group of receptors are activated, whereas the passive test selectively addresses receptors in the pdl which are missing after the extraction of the tooth that was previously in the region of the implant.

However several studies demonstrate that although the periodontal fibers 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. Studying the active tactile perception of single tooth implants with a natural opposing tooth under LA (6), the question highlighted was in how far the tactile perception is to be attributed to the periodontal receptors of the natural antagonist. The answer is that the tactile perception 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.

Moreover, ATS of single-tooth implants was compared with that of teeth (7). The average values for teeth and implants was 21.4 μm and 30 μm, slight but statistical significative.

Performing directional cutaneous kinaesthesia (DCK) and graphesthesia (G), (15)on the buccal side of the alveolar mucosa before and at planned intervals after implant placement, it was found that tactile function is reduced after tooth loss, when it’s compared with implant-supported prostheses.

In fact, sensory and motor feedback to the central nervous system can be restored by implant-supported full dentures (16). Activation of the primary sensorimotor cortex, observed with MRI, in patients with implant-supported dentures might explain the improved tactile, stereognostic ability and mastication functions, which are more similar to the natural dentition. Peri-implant soft tissues could be partially involved in the

osseoperception function.

Another study suggests that conventional CDs presented a significant loss of the inter-occlusal tactile threshold for micro-thicknesses. Fixed or removable implant-supported prostheses allowed for the recovery of the interocclusal tactile threshold at levels similar to that of natural teeth (17)

A recent finding helped us to uncover the tendency that the immediately placed and loaded implants carries an improved peri-implant innervation pattern, including higher nerve density, larger fibre diameter and axon diameter, and more axonal myelination (18). These current histological findings on these regenerated nerve fibres may expand the concept of osseoperception to more challenging levels and may evolve with osseointegration in the oral environment.

The physiological integration of osseointegrated implants indicated the presence of peri-implant innervations: nerve fibres, both myelinated and unmyelinated, in human peri-implant bone, but no differentiated nerve endings could be observed around the implants (19) This showed the role of peri-implant bone in the osseoperception phenomenon.

In addition with these recent findings, for the first time a sensation (osseoperception) has been elicited by electrical stimulation of endosseous oral implants and correlated with simultaneously recorded trigeminal somatosensory-evoked potentials (TSEPs)(20). With the injection of a topical anesthesia in the gingiva surrounding the implants in six individuals, it had little effect on the sensory responses. This evidence excluded peri-implant mucosal innervation as the origin of the perception and of the somatosensory-evoked waves elicited by the electrical stimulation of the oral implants.

Finally, cortical correlates of osseoperception were revealed by punctuate a mechanical stimulation of osseointegrated dental implants, using functional magnetic resonance imaging (fMRI), were activated primary and secondary somatosensory areas in the cortex(21) Moreover, it suggested that brain plasticity occurs when endosseous implants were placed in the extracted teeth region. This cortical activation may represent the underlying mechanism of osseoperception.

4.3 Explain the importance of a setting methodology for assessment and rehabilitation of the motor control function based on a visual feedback.

These arguments are linked to one element: the importance of the periodontal ligament. The impairment or absence of sensory signaling from PMRs causes in subjects altered behavior, including inadequate control of the hazelnut during the first chewing cycle, then an impaired performance during the natural biting task employed here (22, 23).
The receptors in the periodontal ligament play a significant role in the specification of level, direction, and point of attack of forces used to hold and manipulate food between the anterior teeth. Moreover, other types of mechanoreceptors can't fully compensate for the loss of periodontal receptors. (8)
Thus, it's necessary a setting methodology for assessment and rehabilitation of the motor control.
Several studies using a visual feedback (24, 25)
Force measurement was performed with a piezoresistive force transducer (Flexiforce A201, Tekscan, US), with sensitivity of 0.05 V/lb (the transducers will be two in the bilateral force measurement).
Sensors were housed in a cuff made up of different layers that includes two inner metal disk (diameter= 10 mm), which protect each sensor and distributed the clenching pressure over their sensing area, and an external rubber layer that slightly yields under the teeth thereby lowering the load under single cusps and offering improves comfort during clenching. The housed sensor were inserted into a disposable latex glove, from protection from saliva.
The overall thickness of the cuff was 9 mm and decreased to about 5 mm under teeth pressure during clenching [16-17].
In addition, each sensor presented a graduated handle allowing for its precise repositioning in different sessions.
The force signals, from the unilateral or bilateral transducers, were acquired on a computer and were used as coordinates for the instantaneous position of a cursor on a screen, which provides the subject with a visual feedback of the exerted clenching force. The acquisition software is developed under LabVIEW.
The subjects sat on a comfortable chair without head support, with the trunk in an erect

posture and natural head position. First, they familiarized with the device, learning to "drive" the cursor on the screen by modulating the total clenching force and its distribution between the left and right side.

In the unilateral bite force protocol, the force produced during an MVC (maximum voluntary contraction) lasting 7 s, will be recorded three times separated by 2-minutes resting periods. The force signal was low-pass filtered with a 0.5- second moving average and the maximum value that will be observed over the three contractions would be taken as MVC and used as reference for the exercise in that session; the procedure was performed for both sides in random order at the beginning for each session.

The task consisted in a sequence of three different target force levels (10%, 30%, 50% and 70% of MVC), that was recorded with the feedback before and then without it (six repetitions per side). The subjects were instructed to regulate the clenching force so as to reach and maintain as precisely as possible the level indicated by the target.

Each target will be maintained for 5 s and separated from the next by a 5-s resting interval and we will record in central 3 s. The subjects started with the right or left side on a randomized basis.

The exerted force was continuously acquired during each exercise and saved for offline processing.

In analogy in the bilateral bite force protocol (25), the range of movement (ROM), the *range of force (ROF*) was defined to describe the physiological limits of this bilateral isometric contraction. Based on the present setting, these limits correspond to the range of movement of the cursor on the screen. For each subject, the individual ROF will be constructed as a polygon on the bidimensional space defined.

While holding in place the bilateral force sensor, the subject were asked to perform a maximal clench on the left side (Ly) while trying to minimize the load on the right side (Lx). This was followed by a maximal contraction of the right side (producing the force Rx on the right side and Ry on the left), and by a maximal bilateral contraction (producing the force BILx on the right side and BILy on the left). Each contraction will last 3 s and it will be separated from the next by a 1-min interval. This sequence was repeated two times, separated by 2 min of rest. The maximum value in each contraction was considered for the definition of the ROF. The alpha angle is considered as an indicator of the independence of the bite force generated by the two sides.

To limit the development of muscle fatigue during the task, a working area is defined equal to the ROF scaled down by 30%.
The task consisted in controlling the cursor position, by independently grading the force on the two sides of the jaw, to match the position of 12 targets, randomly generated within the working area, according to a uniform probability density function.
Each target was displayed for 5 s and separated from the next by a 5-s resting interval and we were record in central 3 s.
The whole sequence of 12 targets was repeated with the visual feedback before and then without it. The exerted force was continuously acquired during each exercise and saved for offline processing.
The visual feedback is a valid help for the rehabilitation of the motor control.

4.4 Conclusions

There is an important evidence: the impairment or absence of PMRs caused in subjects altered oral behavior.
Thus, it's essential to develop the oral rehabilitation, because there are more several studies on healthy subjects(24, 25), but repeated biting task in healthy volunteers don't show changes in the optimization of the jaw muscle activity and fine motor control(26).
Moreover, it seems useless to invest in these branch of rehabilitation and dentistry.
In the future, I hope that the rehabilitation through visual-feedback may have a relevant role for the assessment and rehabilitation of the neuromusculoskeletal disorders affecting the orofacial system.

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