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Morphofunctional aspects of dental implants

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SUMMARY

Although *oral implantology* is among the most beneficial developments of modern dentistry, the widely spread opinion that the long-term outcome of implants is superior to that of natural teeth has been refuted. To evade uncritical extractions, the morphofunctional properties of natural teeth and implant-supported restorations are compared from a proprioceptive and occlusal trauma perspective. The periodontal ligament of natural teeth provides the central nerve system with feedback for sensory perception and motor control. Conversely, the lack of such proprioception causes lower tactile sensitivity and less coordinated masticatory muscle activity in implant–borne restorations and makes them more prone to occlusal overload and possible subsequent failure. Moreover, occlusal anomalies may be conducive to parafunctional activity, craniomandibular disorder, tinnitus, and headache.

Oral implantology, therefore, has to take appropriate account of *occlusal conditions* and the *biomechanical* and *neuromuscular aspects* of masticatory function.

1. Introduction

Oral implantology is definitely among the most beneficial developments of modern dentistry. The predictable implant-based restoration of aesthetic and masticatory function in fully or partially edentulous patients has become accomplishable in recent years, with reported success rates exceeding 90%.

The triumphal procession of oral implantology may be considered tantamount to an oath of disclosure of restorative dentistry and periodontology. The natural teeth provide the basis of any physiologic balance. Prevention of tooth decay and loss has too long been neglected in dentistry. Till (1999) founded the "*No-Cavity Clinic*" at the University of Minnesota which was one of the first clinical programs to focus on preventive care. After nearly 30 years, however, the preventive paradigm of modern dentistry still cannot be ubiquitously taken for granted. Moreover, occlusal and functional imperfections have too long been tolerated, when conservative treatment was indicated. Yet, occlusal morphology is pivotal to the functional outcome of conservative or prosthodontic treatment. "*Form is function*" or "*if the form isn't there, the function isn't there*".

However, the enthusiasm for dental implantology needs to be somewhat dampened, too. The expanded scope of treatment options has not made evidence-based decision-making easier. With the widely spread (but refuted) opinion that the long-term outcome of implant restorations is superior to that of natural teeth, the willingness among dentists has increased to extract teeth that are compromised for either periodontal or endodontic reasons, but could as well be salvaged with conventional treatment (Holm-Pedersen et al., 2007; Gotfredsen et al., 2008; Lundgren et al., 2008; Carlsson, 2009).

Since dental implants became a common method of replacing missing teeth, numerous studies have been performed on histological, microbiologic and biomechanical aspects, while the neurophysiological integration of implant-supported prostheses has received less attention. To avoid periodontal or endodontic treatment of non-conservable teeth on the one hand, and uncritical extraction and implantation on the other, we have to shed some light on the morphofunctional properties of natural teeth and implant-supported restorations and to compare them from a proprioceptive and occlusal trauma perspective.

2. Aspects of masticatory function

In the undisturbed masticatory system, teeth in terminal occlusion are interlocked like toothed wheels (Fig. 1). The natural interplay of cusps and fissures is characterized by undisturbed eccentric movements (Fig. 2). Spatial excursion of teeth occurs upon chewing-related loading. As a prerequisite, the periodontium possesses resilient and absorptive properties. The neuromuscular network of masticatory function is partly coordinated with afferent information from the periodontal ligament. Periodontal

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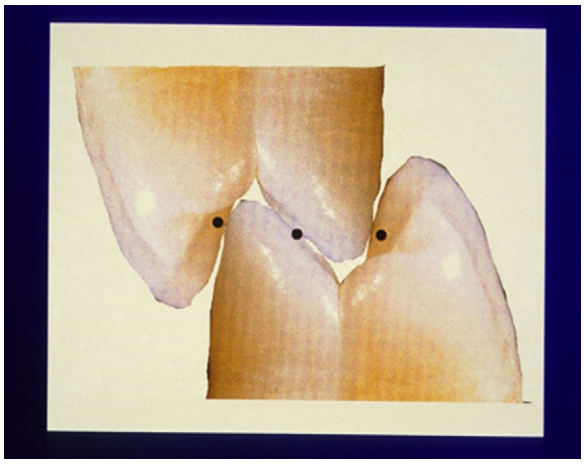

Fig. 1. Natural teeth are interlocked like gear wheels at maximum intercuspation.

mechanoreceptors provide the central nerve system with feedback for sensory perception and motor control (Klineberg and Murray, 1999; Hoshino et al., 2004). For as long as 150 years, the high interocclusal perception of teeth has been recognised (Peaslee, 1857), which is why the latter were referred to as "*modified tactile tools*". The active tactile sensibility of natural teeth, viz. interocclusal detection of object thickness and shape, amounts to 10–30 μm (Tryde et al., 1962; Utz and Wegmann, 1986; Meyer and Eichner, 1987). Information provided by the periodontal mechanoreceptors is particularly important for the fine motor control of the jaws. Positional tooth changes caused by the food bolus are registered and transmitted to the central nerve system where the afferent signals are coordinated and converted into efferent signals to the muscular motor units. As a result, chewing is enabled at the right place with adequate force (localisation and consistency of the food bolus). These physiological feedback mechanisms are believed to protect the teeth and periodontal structures from excessive occlusal forces which may cause trauma to supporting tissues and bone (Fig. 3).

Tooth loss or extraction eliminates the periodontal ligament receptors and, thus, disconnects the neural feedback pathways (Lobbezoo et al., 2002). Due to the lacking proprioceptive feedback mechanism, osseointegrated implants show reduced active perception as compared to natural teeth.

In their early studies on oral tactile function, Jacobs and van Steenberghe (1991) and Jacobs et al. (1992) found reduced tactile and thermal sensitivity in implant-supported restorations compared to natural teeth. The authors speculated that the decreased proprioceptive function might partly be compensated by

Fig. 2. The geometry of cusps and fissures allows undisturbed eccentric movements.

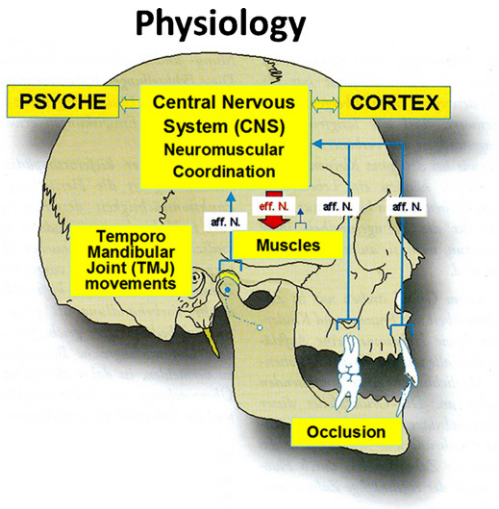

Fig. 3. In the healthy maxillofacial system, receptors located in the tooth, periodontal, muscle and TMJ areas transmit the current condition to the central nervous system (CNS) via afferent nerve pathways (blue arrows: aff.n.). This includes information on the consistency of the food to be masticated. This sensory information determines the corresponding motor activity. Via efferent nerve pathways (red arrow: eff.n.), the appropriate motor activity is enabled in the muscles, so that all masticatory functions can proceed in a coordinated manner. Physiological movement pathways of the TMJ and the individual anterior guidance are shown as dotted lines. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

peri-implant tissues. Later, this phenomenon has been referred to as "*osseoperception*" and defined as mechanoreception derived from TMJ, muscle, cutaneous, mucosal, and periosteal receptors which provide mechanosensory information for oral kinaesthetic sensibility in relation to jaw function and artificial teeth (Klineberg and Murray, 1999; Trulsson, 2005).

Subsequent 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 (Hämmerle et al., 1995; Keller et al., 1996). In a recent study, additionally incorporated implants were reported to reduce the tactile perception in combined implant–tooth-supported dentures (Brunzel et al., 2007). The tactile threshold of natural abutment teeth measured with incorporated dentures was 2 times higher than measured without prostheses.

Food holding and biting behaviour of individuals lacking periodontal receptors was investigated by Trulsson and Gunne (1998). Their results demonstrate a marked disturbance in the control of precisely directed, low biting forces 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.

Surface EMG of the masseter and temporal muscles was performed during unilateral gum chewing and during maximum teeth clenching (Ferrario et al., 2004). Patients with fixed implant-supported prostheses showed significantly inferior neuromuscular coordination during chewing with altered muscular patterns, and less left/right symmetry compared to subjects with natural dentition.

Other studies similarly revealed a less coordinated masticatory muscle activity in implant patients compared to natural dentition (Gartner et al., 2000; Tartaglia et al., 2008).

3. Aspects of occlusal interferences

Due to the deficient proprioceptive input, osseointegrated implants, unlike natural teeth, react biomechanically in a different