Review
Occlusion on oral implants: current clinical guidelines

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SUMMARY Proper implant occlusion is essential for adequate oral function and the prevention of adverse consequences, such as implant overloading. Dental implants are thought to be more prone to occlusal overloading than natural teeth because of the loss of the periodontal ligament, which provides shock absorption and periodontal mechanoreceptors, which provide tactile sensitivity and proprioceptive motion feedback. Although many guidelines and theories on implant occlusion have been proposed, few have provided strong supportive evidence. Thus, we performed a narrative literature review to ascertain the influence of implant occlusion on the occurrence of complications of implant treatment and discuss the clinical considerations focused on the overloading factors at present. The search terms were ‘dental implant’, ‘dental implantation’, ‘dental occlusion’ and ‘dental prosthesis’. The inclusion criteria were literature published in English up to September 2013. Randomised controlled trials (RCTs), prospective cohort studies and case–control studies with at least 20 cases and 12 months follow-up interval were included. Based on the selected literature, this review explores factors related to the implant prosthesis (cantilever, crown/implant ratio, premature contact, occlusal scheme, implant–abutment connection, splinting implants and tooth–implant connection) and other considerations, such as the number, diameter, length and angulation of implants. Over 700 abstracts were reviewed, from which more than 30 manuscripts were included. We found insufficient evidence to establish firm clinical guidelines for implant occlusion. To discuss the ideal occlusion for implants, further well-designed RCTs are required in the future.

KEYWORDS: dental implants, dental occlusion, evidence-based dentistry, clinical guideline, dental prosthesis, clinical trial

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Introduction
Dental implants have been extensively used for oral reconstruction of partial and complete edentulism. Although many clinical studies have shown high success rates with dental implant treatments (1–4), several studies have reported failures and complications for diverse reasons. One of these reasons is overloading resulting from improper occlusion (5). Overloading refers to stress around the implant components and bone–implant interface that is not biologically acceptable. Dental implants frequently suffer from occlusal overload because the prostheses lack the supporting periodontal ligaments that are known to provide the shock-absorbing function of natural teeth. Additionally, dental implants exhibit low tactile sensitivity and low proprioceptive motion feedback because of the absence of periodontal mechanoreceptors (6). Therefore, it was said that conventional occlusal concepts must be modified to reduce the occlusal force on implant prostheses and offer some protection. Some examples of these changes include narrowed occlusal table, reduced cuspal inclination, correction of load direction, reduced non-axial loading, reduced length of the cantilever and lighter occlusal contacts on implant prostheses (7). Misch
proposed that occlusal adjustments are necessary to eliminate mobility differences between the implants and the teeth during heavy biting (8). Furthermore, Rangart et al. (9) reported that regular re-evaluation and periodic occlusal adjustments were necessary to prevent the potential overload that occurs with the positional changes of natural teeth. There are currently numerous guidelines and theories that indicate concrete occlusal schemes along with variations in dentition and the types of prosthesis used to obtain proper implant occlusion. Although all of these propositions appear to be practical for the clinical setting, they are not sufficiently supported by research based on clinical outcomes. The ideal implant occlusion would allow controlled stress around the implant components, provide a prosthetically and biologically acceptable bone–implant interface and obtain long-term stability of the marginal bone and prosthesis. However, it is not clear that the occlusion for oral implants needs to differ from that in the natural dentition. Here, we undertook a narrative literature review to seek the influence of implant occlusion on the occurrence of complications in implant treatment and to discuss the clinical considerations associated with overloading factors.

Methods

A search of English language literature was conducted to examine the existing scientific evidence for the current clinical guidelines and strategies for implant occlusion using Medline/PubMed (http://www.ncbi.nlm.nih.gov/pubmed) in September 2013. The search terms were ‘dental implant’, ‘dental implantation’, ‘dental occlusion’ and ‘dental prosthesis’. Abstracts of the following types of articles were reviewed: Randomised controlled trials (RCTs), prospective cohort studies and case–control studies that included at least 20 cases and 12 months follow-up interval. Furthermore, literature was also selected that examined aspects of implant occlusion such as the implant prosthesis factors (cantilever, crown/implant ratio, implant–abutment connection, splinting implants and tooth–implant connection) and factors pertaining to the dimensions of the implant (diameter, length and angulation of implants) or number of implants used in the case and had evaluated either of the following aspects: biological complications (marginal bone level and implant survival rate, e.g.: the presence of the implant in the oral cavity regardless of marginal bone loss) or mechanical complications (prosthesis survival rate, component fracture and screw loosening). Over 700 abstracts were reviewed, from which more than 30 manuscripts, which were related to the overloading factors of implant occlusion, were included (Table 1). In this review, large sample sizes were defined as over 50 mean patients, and long observation periods were defined as over 60 months mean observation period.

Results

Number of implants

Implant-retained overdenture for edentulous jaws. Seven studies (10–16) were selected to determine whether there is a difference in the marginal bone level and implant survival rate between the use of two or more implants in fully edentulous patients with an implant-retained overdenture (Table 2). Additionally, the marginal bone level and survival rates were evaluated between the bar and ball systems, as determined based on 2 RCTs (17, 18) (Table 3).

In mandibular reconstructions, the marginal bone level and implant survival rates are not significantly different for two implants with a bar, two implants with ball attachments and four implants with a bar, based on 6 RCTs (10–15) with large sample sizes and long observation periods. The marginal bone level and implant survival rates are not significantly different between bar and ball attachments based on 2 RCTs (17, 18) with small sample sizes and long observation periods. Because of the high bone density, it is

| Table 1. Reviewed issues regarding the overloading factors of implant occlusion |
|---------------------------------------------|----------|
| Implant | Number of implants |
| Implant diameter | [3] |
| Implant angulation | [2] |
| Prosthesis | Cantilevers | [4] |
| | Crown/Implant ratio | [1] |
| | Implant–abutment connection | [0] |
| | Cement or screw retained reconstruction | [0] |
| | Implant–tooth connection | [4] |
| | Timing of loading | [8] |
possible to obtain good results with an implant-retained overdenture in the mandible with a minimum of two implants positioned between the right and left mental foramina.

In maxillary reconstructions, the marginal bone level and implant survival rates are not significantly different for four or six implants with bars; however, this is based on only 1 RCT (16) that had a small sample size (n = 49) and a short observation period (12 months). This RCT indicated that a minimum of four implants is necessary to retain the maxillary overdenture.

**Fixed prostheses for edentulous jaws.** Five studies (19–23) were selected to determine whether there is a difference in the marginal bone level between four or more implants in fully edentulous patients with implant-supported fixed prostheses (Table 4).

In mandibular reconstructions, there is no difference between four or more implants in terms of marginal bone level and survival rates based on 3 RCTs (19, 21, 22) with large sample sizes and long observation periods.

In maxillary reconstructions, there is no difference between four or six implants in terms of marginal bone level and survival rates for maxillary surgeries, based on 2 RCTs (20, 23) with small sample sizes and short observation periods.

**Fixed prostheses for partially edentulous jaws.** Neither RCT nor other prospective study was found directly comparing the number of implants in partially edentulous conditions. One controlled clinical trial (24) was selected to determine whether there is a difference in the marginal bone level between the splint and non-splint group in the partially edentulous posterior maxilla. In this study, 44 patients received three adjacent implants with splinted or non-splinted cement-retained fixed prostheses, observed over 60 months. There was no statistically significant difference between the groups in the mean marginal bone level at the 5-year recall.

**Implant diameter**

Three studies (25–27) were selected to determine whether there is a difference in the marginal bone level between wide diameters or other diameter implants (Table 5).

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Table 2. Selected studies concerning the number of implants in overdentures

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year of publication</th>
<th>Study design</th>
<th>Sample size (patients)</th>
<th>Region</th>
<th>Anchorage system</th>
<th>Implant survival rate (%)</th>
<th>Marginal bone level at 5-year recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batenburg et al. (10)</td>
<td>1998</td>
<td>RCT</td>
<td>58</td>
<td>Mandible</td>
<td>2 implant bar/4 implant bar</td>
<td>99/93/100</td>
<td>No statistically significant differences</td>
</tr>
<tr>
<td>Wismeijer et al. (11)</td>
<td>1999</td>
<td>RCT</td>
<td>102</td>
<td>Mandible</td>
<td>2 implant ball/2 implant bar</td>
<td>100</td>
<td>No statistically significant differences</td>
</tr>
<tr>
<td>Visser et al. (12)</td>
<td>2005</td>
<td>RCT</td>
<td>56</td>
<td>Mandible</td>
<td>2 implant ball/4 implant bar</td>
<td>99/100</td>
<td>No statistically significant differences</td>
</tr>
<tr>
<td>Mjeler et al. (13)</td>
<td>2009</td>
<td>RCT</td>
<td>50</td>
<td>Mandible</td>
<td>1 implant ball/2 implant bar</td>
<td>81/100</td>
<td>Patients with two implants show less marginal bone loss than those with four implants</td>
</tr>
<tr>
<td>Kronstrom et al. (14)</td>
<td>2010</td>
<td>RCT</td>
<td>33</td>
<td>Mandible</td>
<td>4 implant bar</td>
<td>99</td>
<td>No statistically significant differences</td>
</tr>
<tr>
<td>Stoker et al. (15)</td>
<td>2012</td>
<td>RCT</td>
<td>110</td>
<td>Maxilla</td>
<td>4 implant bar/6 implant bar</td>
<td>99/93/100</td>
<td>No statistically significant differences</td>
</tr>
<tr>
<td>Slot et al. (16)</td>
<td>2013</td>
<td>RCT</td>
<td>49</td>
<td>Maxilla</td>
<td>4 implant ball/6 implant bar</td>
<td>99</td>
<td>No statistically significant differences</td>
</tr>
</tbody>
</table>
Based on 3 prospective cohort studies with large sample sizes and long observation periods, the diameter of the implants did not seem to influence implant survival rate.

**Implant angulation**

No RCT was found directly comparing angulation of implants. Two prospective studies (28, 29) were selected to determine whether there is a difference in the marginal bone level between vertical and angulated implant placements in maxillary reconstructions (Table 6).

When bone resorption is severe, it is impossible to place an implant in the ideal position beneath the prosthesis, thus requiring angulation. No difference in implant and prostheses survival rate was determined with large sample sizes and short observation periods. In terms of reducing the invasiveness of the implantation in older patients, the use of angulated implant placement could be an effective option.

**Cantilevers**

Four prospective cohort studies (30–33) were selected to determine whether there is a difference in the marginal bone loss for reconstruction with and without cantilevers (Table 7).

In cases where anatomical constraints make it difficult to place the implant, the prosthesis may comprise cantilever extensions. Based on 4 RCTs with small sample sizes and long observation periods, no difference in marginal bone level between reconstruction with or without cantilevers was reported; however, technical complications were frequently observed with cantilevers than without cantilevers. Therefore, prostheses with cantilevers should be checked not only for changes in the marginal bone level, but also for screw loosening or other changes in the occlusal contact and vertical dimension of the prosthesis.

**Crown/implant ratio**

One prospective cohort study (34) was selected to determine whether there is a difference in the marginal bone level with regard to the crown-implant ratio.

During bone resorption, the clearance between the opposing teeth and/or the alveolar ridge is increased. This leads to an imbalance between the length of the implant and the prosthesis. No significant difference in marginal bone level with regard to crown-implant ratio was found with a large sample size \((n = 109)\) and short observation period (53 months) (34). The current available evidence suggests that the crown/implant ratio does not affect marginal bone level.

**Implant–abutment connection**

No RCT or other prospective studies that directly compare internal and external connections could be found. Gracis et al. (35) performed a meta-analysis to assess screw loosening among other factors using 4 RCTs, 13 prospective and 2 retrospective studies. Implant–abutment connection systems are broadly classified into two categories: external and internal connections, and they reported that screw loosening was likely to occur with external connections rather than with internal connections.

**Cement- or screw-retained reconstruction**

No RCT or other prospective studies that directly compared cement- and screw-retained reconstructions could be identified in this review. Sailer et al. (36) reviewed 3 RCTs and 11 prospective studies that partly included information on this topic. They found
that cement-retained reconstructions exhibited more serious biological complications. They found that 2.8% of patients had a marginal bone level of >2 mm in cement-retained crowns as compared with 0% for screw-retained crowns over a 5-year period. Comparatively, however, the screw-retained reconstructions exhibited more technical problems, with an estimated 5-year incidence of technical complications of 24.4% as compared with the 11.9% for cement-retained crowns. Both types of reconstruction had a negative effect on the clinical outcomes, with neither method clearly advantageous over the other.

**Tooth–implant connection**

Four RCTs (37–40) were selected to determine whether there is a difference in the marginal bone level between studies where a connection was made between the implant and natural tooth or not (Table 8).

No significant differences in marginal bone level were found between cases with or without connection between the implant and natural tooth based on 3 RCTs with small sample sizes and long observation periods. However, there was a high incidence of intrusion based on 1 RCT with small sample sizes and long observation periods. Implants exhibit different displacement characteristics in response to loading when compared with natural teeth. Thus, in cases where tooth–implant connection is required, it is necessary to carefully monitor for intrusion of the natural tooth.

**Timing of loading**

Eight RCTs (41–48) were selected to determine whether there is a difference in the marginal bone level between immediate, early and conventional loading of implants (Table 9).

Advances in basic and clinical research have led to improvements in surgical techniques, in the design of fixtures and in the characteristics of implant surfaces, resulting in a shortened healing period, with different loading protocols selected for different patients. There was no significant difference between immediate, early and conventional loading of implants in terms of marginal bone level as well as implant survival rates in RCTs with large sample sizes and short observation periods.
Although there are numerous studies concerning implant occlusion, most demonstrate poor study design and ambiguous results and are thus possibly unreliable. In an earlier review, we reported that many studies regarding the stomatognathic function of specific occlusal schemes are of low quality because of poor study design, with little scientific evidence to support that one specific occlusal scheme is superior.
to another in terms of its clinical outcome, such as longer survival of the prosthesis/residual teeth, periodontal breakdown, tooth/prosthesis wear, chewing efficiency, and bony change in the TMJ, among others (49). Few studies have actually sought to compare the difference in guidance applied to the implant. The aforementioned study (34) found no significant difference in marginal bone level with regard to occlusal table width. Another prospective cohort study with a large sample size ($n = 56$) and short observation period (2–3 months) (50) compared the difference between canine guidance, group function and balanced occlusion. They found that canine guidance is a risk factor for gold screw loosening. Comparatively, Carlsson et al. (51) reported that the principles and methods applied in conventional prosthodontics can, in general, be used also for implant prostheses. Within the literature, there is relatively reliable scientific evidence concerning the number of implants and timing of loading that can be followed to obtain successful results with dental implants. Despite these findings, the review was overall unable to identify a specific occlusal scheme for implant occlusion from the current body of literature that provides successful results with sufficient scientific support.

**Conclusion**

There was insufficient evidence to establish clinical guidelines for implant occlusion. Further well-designed RCTs are required in the future. Implant occlusion should be examined not only in terms of conventional occlusal schemes but also from the standpoint of the role of overloading factors. These are the factors related to the load-bearing function by marginal bone as well as implant components.

**Disclosure**

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**References**


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