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## Dental occlusion: modern concepts and their application in implant prosthodontics

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**Abstract** The aim of this article was to review the literature on various aspects of occlusion related to implant prosthodontics, using PubMed and the Cochrane library. Even if the number of studies on implants and prosthodontics is very large, no randomized controlled trials or Cochrane reviews were found on the possible influence of occlusal design or characteristics of occlusion on treatment outcome. Therefore, studies and articles of a lower evidence level were accepted as the main part of the review. The widely spread opinion that implants are superior to natural teeth was refuted by two recent consensus conferences, which concluded that the long-term outcome of implant restorations is not better than that of natural teeth. No controlled studies on the optimal features of a harmonious natural and/or restored occlusion, including implant prostheses, were found. Nor was there any evidence that more sophisticated methods in jaw registration, e.g., using face-bows and adjustable articulators, compared with simpler methods, will yield better clinical prosthodontic results. This article discusses, among other things, concepts of occlusion of implant-supported restorations, occlusal material, cantilevers, and occlusal risk factors. Within the limitations of the review, it was concluded that many factors can influence implant failure and peri-implant bone loss but that little is known of the relative importance of such factors. Most probably, however, occlusal factors and details of occlusion are in general of minor importance for the outcome of

implant restorations. Occlusion can be managed successfully by using simple methods for jaw registration and different occlusal concepts.

**Key words** Dental occlusion · Oral implants · Removable partial denture · Shortened dental arches · Therapeutic occlusion

### Introduction

For many years, in fact, for more than 100 years, dentists and researchers have debated how to identify and define concepts of dental occlusion that could be applied in diagnostic and therapeutic situations. Occlusion has been, and still is to some extent, a controversial issue in what is now called conventional removable and fixed prosthodontics, and it is not fully resolved in implant prosthodontics. In a survey of the development of concepts – and controversies – of occlusion, Mohl and Robertson<sup>1</sup> noted the increasing interest in biological and behavioral aspects of occlusion in contrast to earlier emphasis on technical and biomechanical principles. They concluded that new information and insights will require continued analysis of our concepts and therapeutic approaches to occlusal problems, which are likely to change over time. Published 20 years ago, this message is still relevant, as indicated in a recent review.<sup>2</sup> Of further interest today is that the statement may include occlusion of implant prostheses as well.

Although numerous questions related to occlusal characteristics cannot be answered with certainty, dentists are every day performing diagnostic and therapeutic procedures that include dental occlusion, e.g., simple fillings, crowns, removable and fixed prostheses, and implant-supported restorations. The outcome of treatment is often quite successful in spite of the fact that dentists use different concepts of occlusion. It is probable that many clinicians have been terrorized by many of the strict theoretical recommendations on dental occlusion, including the concept of “ideal occlusion.” Individuals with an ideal occlusion

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are seldom seen in real life, and the occlusions of most of our patients deviate in one or more ways from the ideal but may still function well. They are physiologically acceptable and do not need any intervention.<sup>2-5</sup> These suggestions were originally formulated for occlusion of the natural dentition and conventional prosthodontic therapy. It is not well known if they are applicable also in implant prosthodontics.

The purpose of this article was therefore to review the literature on various aspects of occlusion related to implant prosthodontics. It was hypothesized that various principles of occlusion can be used and that there is no evidence that any single concept is superior to others.

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## Material and methods

The dental literature was searched via Medline/PubMed up to November 2008 using various combinations of the following terms: dental occlusion, dental/oral implants, prosthodontics, occlusal design, occlusal loading, occlusal risk factors, and bruxism. The Cochrane library was searched for reviews on dental implants and occlusion. A manual search regarding occlusion and implant prosthodontics was performed based on references in the found articles. The inclusion criteria were articles presenting studies on the influence of occlusal variables related to the outcome of treatment with implant-supported prostheses.

### Results of the literature search

The search of PubMed with the combination of dental occlusion and implants revealed 919 titles, of which 21 were classified as randomized controlled trials (RCTs). However, none of these included analyses of the influence of occlusal design or characteristics of occlusion on treatment outcome. In the Cochrane library, no reviews on dental implants and occlusion were available. Five of the RCTs and two Cochrane reviews analyzed the timing of placing and loading of implants, and this aspect was therefore included. The manual search could not identify any additional relevant studies. The titles of the 919 articles listed by PubMed had already revealed that the great majority of the articles were of no interest for this review and therefore were excluded. Abstracts of 112 potentially relevant articles were read, and 80 full papers were reviewed, of which 33 presented studies that fulfilled the inclusion criteria. The remaining part of the reviewed literature presented in the reference list consists of reviews (preferably systematic ones) and a few opinion papers and chapters in textbooks of interest. The original aim of a systematic review based on RCTs, which are considered to give the best evidence,<sup>6</sup> was thus not accomplished. Studies and articles of a lower evidence level have therefore been accepted for the review, as suggested in other recent systematic reviews.<sup>7,8</sup> Only 3.6% of the originally listed titles proved to be studies that were in accordance with the inclusion criteria.

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## Results regarding the literature on dental implants and prosthodontics

The dental literature is increasing in such a rapid way that it is impossible for a single person to read all published material. The number of articles in prosthodontics during the 5-year period 2001 to 2005 was almost 10000,<sup>6</sup> and for the last 12-month period up to November 2008, PubMed listed 2176 publications. In a survey of the development of prosthodontic publications during the past four decades, it was shown that literature on implant prosthodontics was the most expansive field with an almost exponential increase of articles, whereas studies on removable prostheses exhibited a drastic decrease during the past two decades.<sup>9</sup>

Reviews have been the traditional way to help people with a comfortable overview of current literature. It is obvious, however, that conventional reviews may have disadvantages that may lead to wrong interpretations of the literature. A serious drawback is the risk that the authors base the inclusion and exclusion of studies selected on a preconceived opinion of the topic of review, but there are a number of other possible risks (Table 1). To overcome such disadvantages, strict guidelines for so-called systematic reviews have been proposed. A systematic review is defined as “the application of scientific strategies that limits bias to the systematic assembly, critical appraisal, and synthesis of all relevant studies on a specific topic.”<sup>10</sup> They are considered to facilitate the extraction of the best possible evidence from the available literature. Systematic reviews have undoubtedly improved the situation, but there is still room for improvement.<sup>11</sup> Systematic reviews have been used as a basis for several consensus conferences during the past few years.<sup>8,12,13</sup> The strategy of a systematic review is first to formulate the question to be examined, identify inclusion and exclusion criteria for the studies to be reviewed, and then to scrutinize the literature. For example, a review of studies on dental occlusion and implants starts with a search of publications, e.g., in PubMed/ Medline, for a specific time period. Of the titles revealed by the search, many must be excluded because they are not in line with the inclusion criteria. The abstracts of the remaining articles are read, and of those fulfilling the criteria of the review, the full articles are scrutinized. For most systematic reviews, only a small fraction of the original hits of the search remain for the final review. For example, in a systematic review of survival of single crowns and fixed dental prostheses only 1% of the original number of titles remained for the final review.<sup>7</sup>

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**Table 1.** Possible disadvantages in conventional literature reviews

- Inclusion and exclusion of studies may be author-biased/subjective
  - A review is retrospective and subject to bias
  - Publication bias (lack of negative findings)
  - Use of “academic results,” seldom from general practice
  - Not all literature is searched
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## Implants or teeth

The widely spread opinion that implants are superior to natural teeth and can solve all problems in prosthodontics can be seriously questioned. The most important obstacle is economic: most edentulous people are poor and cannot afford the high cost of implant treatment.<sup>14,15</sup> However, even when cost was removed as a factor, more than one-third of older edentulous subjects refused an offer of free implants, preferring to retain their mandibular dentures.<sup>16</sup>

There are no RCTs comparing the outcome of restorations on implants with those on natural teeth. However, reviews on the long-time survival of these two treatment options have found a trend to greater incidence of complications with implant-supported than tooth-borne prostheses.<sup>17,18</sup> A meta-analysis of various restorative therapies showed that fixed dental prostheses on teeth had a higher 10-year survival than those on implants.<sup>19</sup> In two recent consensus conferences the question of implants or teeth as support for dental replacements has been examined. Both came to similar conclusions. The first one found that “oral implants will not yield a more predictable outcome after e.g. 10 years of service ... than natural teeth.”<sup>20</sup> The question “Have implants a better prognosis than teeth with reduced marginal bone support?” was answered in the following way at the other conference: “The survival rate of teeth in periodontally well-maintained patients are in general higher than that of implants.”<sup>8</sup> These conclusions were in both conferences interpreted so that teeth should be given priority whenever possible. “Oral implants represent the last resource: they are not replacing teeth; they should replace missing teeth.”<sup>20</sup>

## Concepts of occlusion

The dental literature has presented numerous opinions on desired characteristics of occlusion of the natural dentition as well as for prosthodontic restorations. Examples of suggested issues for analyses of occlusion have been number of teeth, jaw relationships, occlusal contacts, occlusal interferences, and occlusal stability. The opinions on such issues have varied much over time; they have often been conflicting and caused much confusion, much of which is still not fully resolved.<sup>1,2</sup> In a recent textbook on occlusion using an evidence-based approach, it was stated that there are no controlled studies on the optimal features of a harmonious natural and/or restored occlusion.<sup>21</sup> It must be concluded that confusion remains concerning optimal occlusal relationships.

In discussions of occlusion, principles for jaw registration are usually included. The literature on jaw registration reveals a considerable methodological variation and controversies regarding selection of articulators and use of face-bows, for example.<sup>22-24</sup> Although it was a trend in earlier literature to hint that the more sophisticated the methods were, the better the prostheses would be, such a statement has never been proved. In fact, most full-mouth restorations at Scandinavian centers during past decades have been fab-



**Fig. 1.** Average mounting of a mandibular cast with the occlusal plane aligned parallel to the upper articulator member. The maxillary cast is to be placed for mounting with an interocclusal record

ricated on semiadjustable articulators used as mean-value instruments, without use of a face-bow. The same is true for implant-supported prostheses, of which so many successful long-term studies have been presented from Scandinavia.<sup>22</sup> The casts are mounted with the occlusal plane aligned parallel to the upper articulator member and with mean-value setting of the instrument (Fig. 1).

## Shortened dental arches

In prosthodontic decision making, the old dogma that tooth loss must always be replaced needs to be revised. The shortened dental arch (SDA) concept, first discussed internationally by the Dutch prosthodontist Professor Käyser in 1981,<sup>25</sup> has proven to be worth serious consideration in treatment planning for partially edentulous patients. A review of the prolific literature on SDA concluded that “shortened dental arches comprising anterior and premolar teeth in general fulfill the requirements of a functional dentition.”<sup>26</sup> In the original Brånemark implant treatment,<sup>27</sup> a moderate SDA concept was applied (Fig. 2). In spite of the lack of complete molar support, excellent long-term functional outcome has been demonstrated.<sup>19,28,29</sup> Although not everybody agrees with the SDA concept, no systematic clinical study with conflicting results was found.<sup>26</sup> However, subjects with extreme SDA may exhibit functional problems.<sup>30</sup> A recent Japanese study found that for full satisfaction of masticatory function at least one pair of opposing first molars was necessary.<sup>31</sup> Nevertheless, it seems that most of the recent literature accepts the opinion that acceptable dental occlusion is possible in subjects with a reduced dentition. How many teeth are required cannot be answered in general but must be evaluated individually with respect to the wide

variation in occlusal morphology and individual adaptability present in the population.<sup>15,32</sup>

In conventional prosthodontics, the first choice for replacing missing teeth was in general a removable partial denture. Comparisons of two options for treatment of SDA, a removable partial denture and small fixed dental prostheses, have demonstrated several advantages for the fixed prostheses in spite of the fact that they did not provide molar support. The patients liked them better than the removable denture, which led to more caries and other maintenance problems over 5-year periods.<sup>33,34</sup> It has also been found that removable partial dentures do not provide better chewing comfort and stability of occlusion or prevent or cure temporomandibular disease (TMD) problems.<sup>26,35,36</sup> Other studies have shown that a great number of patients (20%–50%) who received removable partial dentures stopped wearing them after some time. With such clinical results and the increasing acceptance of the SDA concept,

the indications for removable partial dentures have diminished.<sup>37</sup>

Oral implants have an enormous potential as a treatment option in modern prosthodontics. Originally prescribed for totally edentulous patients, they are now increasingly used in partial edentulism. There are no published RCTs comparing modern implants and conventional prostheses in patients with SDAs. Even if it can be assumed that implant prostheses will provide better long-term outcome than a removable partial denture, the possibility to avoid replacement of the lost molars should be considered according to the SDA concept. In a unilateral SDA, where a removable partial denture is admittedly difficult to fabricate and use, an implant restoration would ideally be the treatment of choice provided resources are available (Fig. 3).

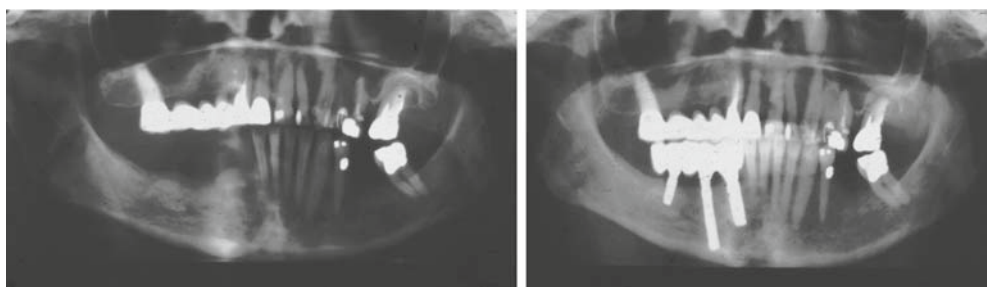
### Therapeutic occlusion

The great diversity of opinions on occlusion-related clinical methods and treatment procedures that have been taught and used over decades has left many clinicians uncertain. A therapeutic occlusion has been defined as one modified by various therapeutic measures so that it falls within the parameters of a physiological occlusion.<sup>5</sup> Among the many varying recommendations for therapeutic occlusions presented in prosthodontic textbooks, a concept of a functionally optimal occlusion originally presented in the 1950s by Beyron<sup>38,39</sup> has gained much support over the years and has been considered to have stood the test of time.<sup>2,40</sup> Some general guidelines for a therapeutic occlusion that have been formulated based on such recommendations are presented in Table 2.<sup>22</sup>



**Fig. 2.** Early full-arch implant-supported restorations according to the Brånemark system using a moderate shortened dental arch (SDA) concept

**Fig. 3.** Unilateral tooth loss in the right mandible treated with an implant-supported prosthesis



**Table 2.** Some general guidelines for a therapeutic occlusion<sup>22</sup>

- Acceptable vertical facial height after treatment
- Acceptable interocclusal distance with the mandible at rest
- Stable jaw relationship with bilateral contact after relaxed closure leading into maximal intercuspation as well as after retruded closure
- Well-distributed contacts in maximal intercuspation, providing axially directed forces
- Multidirectional freedom of contact movements radiating from maximal intercuspation
- No disturbing or harmful intermaxillary contacts during lateral or protrusive excursions
- No soft tissue impingement during occlusal contact

Admittedly, there is no strong evidence in support of a view that all these recommendations must be fulfilled for a successful outcome of prosthodontic treatment. They are, however, indicating a logical and practical approach adhered to by many authors and have probably been helpful to many in achieving the primary goal of occlusal therapy – maintaining and/or improving optimal masticatory function and comfort, including stability of the occlusion. Whether they are sufficient, or necessary, is not known, either for conventional or for implant prosthodontics. As stated in one of the most recent textbooks: “There are no controlled studies on the optimum features of a harmonious natural and/or restored occlusion.”<sup>21</sup>

Regarding occlusal form, the idealized morphology, e.g., including tripodization of contacts, recommended by advocates of more advanced occlusal philosophies, seems to have been replaced by simpler designs.<sup>41,42</sup> The reason is that there is no evidence that the clinical outcome of methods based on the more complex principles is better than that of simpler ones. It has been recommended that the occlusal morphology should have a smooth shape with minimal cusp height and fossa depth. One contact on each opposing tooth in maximal intercuspation is sufficient.<sup>21,42</sup> An international consensus conference stated that there is no evidence to indicate that a particular occlusal scheme design or occlusal form is superior. As an explanation to the similar outcome of implant-borne reconstructions with varying occlusal designs, it has been suggested that complex neurophysiological mechanisms allow the jaw muscle system to accommodate to oral and dental changes.<sup>43</sup> Changes of the occlusal morphology of restorations, both conventional and implant-supported designs, will occur with time. For some of these changes, adjustments may be required to maintain long-term stability and function.

### Occlusion of implant-supported restorations

An interesting question is: Does the occlusion of restorations on natural teeth and on oral implants need to be different? At the early stage of implant prosthodontics, the different attachment between teeth and implants to the bone was emphasized as very important. With the increasing experience of successful implant treatment using varying occlusal principles, this difference seems to be of minor or negligible importance. At present, it seems prudent to accept that principles and methods applied in conventional prosthodontics can in general be used also for implant prostheses.

In spite of the evident differences between the attachment of natural teeth through resilient periodontal ligaments and osseointegrated implants with a rigid bone contact in the jaw, much of oral and masticatory function seems to be similar in natural and implant-supported dentitions.<sup>44–46</sup> The periodontal ligament is lost after tooth extraction, but most of its functional role as related to occlusion and mastication thus seems to be taken over by other mechanisms.<sup>47</sup>

Not much research has focused upon the occlusion of implant-supported restorations, and there are no RCTs comparing different occlusal designs. The recommendations found in the literature usually refer to the principles and methods used in conventional prosthodontics, which again has led to controversies between those who advocate complex techniques and those who believe that simple methods are sufficient. Based on the extremely successful long-term results of implant-supported restorations published from many centers, it may be concluded that a variety of methods related to jaw registration and occlusal morphology are as acceptable for rehabilitation based on dental implants as they are for fixed prosthodontics on natural teeth. The simple principles described above for conventional prosthodontics may therefore be followed also for implant-based restoration. A literature review concluded that the occlusal scheme for an implant-supported restoration should be designed to decrease cuspal interferences, centralize forces along the long axis, and minimize lateral forces; i.e., it should be like that of a similar restoration supported by a natural dentition.<sup>48</sup> However, it is not known how much deviation from those recommendations for occlusal design can be tolerated in implant prosthodontics. A study on the influence of occlusal factors on treatment outcome found considerable divergence from the “optimal occlusion” usually prescribed for implant-supported restorations but without negative consequences for patient satisfaction and clinically and radiographically recorded variables.<sup>49</sup>

The differences between tooth and implant attachment to the jawbone need consideration. It is generally agreed that a natural tooth can be intruded about 50  $\mu\text{m}$  by a light force (20 N) compared to some 2  $\mu\text{m}$  for an osseointegrated implant. It is therefore necessary to check the occlusion in both light and hard biting when there are implant-supported restorations and natural teeth in the same jaw (this is further discussed in the section “Some clinical aspects” below). Since the development of peri-implant and periodontal conditions may differ, it is important to carefully check and when necessary adjust changes in occlusal contacts at the follow-up examinations of such cases.

Cantilever extensions with one to two units are common in implant restorations, seemingly without controversy.<sup>28</sup> In contrast, the cantilevers on restorations on natural teeth may lead to lower survival rate than for fixed dental prostheses (FDPs) with end abutments.<sup>19,50</sup> Even if cantilevers may appear problematic from a biomechanical point of view, no alarming reports of adverse biological effects related to cantilevers have been presented in the implant literature.<sup>51–53</sup> However, the overall incidence of technical complications was reported to be higher in implant restorations with cantilever than in those without<sup>54</sup>; this may differ with respect to the type of restoration. Over a 10-year follow-up period, there were no framework or implant fractures of implant-supported prostheses in the partially edentulous mandible with either laser-welded titanium or gold alloy cast frameworks (with no or short cantilevers).<sup>55</sup> In contrast, the same authors reported fractures of the titanium frameworks, usually with two-unit cantilevers, in 16%



of the patients with implant restorations in the edentulous mandible during a 15-year follow-up.<sup>56</sup> There was no specific analysis of the occlusal forces and dimensions of the frameworks on these restorations that could explain the relatively high incidence of fractures. However, most fractures occurred in the laser welding at the most posterior implant, which might suggest material fatigue related to occlusal loading.

Extensive studies on occlusal forces in patients with implant-supported fixed cantilever prostheses provided interesting results presented in a Swedish doctoral thesis.<sup>46</sup> It was shown, for example, that there is different force distribution in cantilevered implant-supported fixed prostheses depending on the dental status in the opposite jaw, whether complete denture or natural teeth. Closing and chewing forces increased distally along the cantilever beam when occluding with a complete denture, whereas they decreased distally when occluding with natural teeth. In contrast to previous belief, the posterior segment of fixed implant-supported prostheses exhibited larger local forces when occluding with complete dentures than with natural teeth. It was therefore suggested that when occluding with a complete denture, larger dimensions of the cantilever joint and the metal framework are necessary than when occluding with tooth-borne prostheses.<sup>57</sup>

The force distribution pattern could be altered by infra-occluding the posterior cantilever unit.<sup>57,58</sup> Based on these findings, it seems prudent that the most distal cantilever units be slightly infraoccluded (0.1–0.2 mm) to avoid unfavorable loading, particularly so in maxillary restorations.

With respect to available literature and clinical experience, it can be recommended that the cantilever extensions should be of limited length, especially in the maxilla, and the occlusion on cantilever units must be carefully checked to not include premature contacts. At lateral and protrusive excursions, disocclusion of the cantilevers is recommended.

#### Occlusal material

For implant-supported prostheses, it was originally strongly recommended to use a shock-absorbing material such as acrylic resin on top of the superstructure to protect the implant–bone interface. Based on biomechanical analyses, acrylic resin denture teeth were therefore predominant during the developmental years.<sup>27,59</sup> However, biomechanical calculations do not always stand the test in the clinic. In a clinical study on five subjects using fixed prostheses with either acrylic resin or porcelain occlusal surfaces, masticatory forces were recorded while the subjects chewed various foods. No differences related to tooth material could be detected in the load rates.<sup>60</sup> In a study covering 6 years, the use of porcelain instead of composite resin as occlusal material had no influence on the marginal bone height around the implants.<sup>61</sup>

These findings can be interpreted as a support for the use of porcelain as occlusal material because no serious biological consequences of the hard material have been



**Fig. 4.** Fracture of an acrylic resin tooth in a fixed full-arch implant-supported maxillary prosthesis. (Courtesy of Dr. Anders Örtorp)



**Fig. 5.** Extensive wear of acrylic resin teeth of a fixed full-arch implant-supported mandibular prosthesis after 7 years occluding with a fixed metal ceramic dental prosthesis on natural teeth. (Courtesy of Dr. Anders Örtorp)

reported. Furthermore, the most common complications of implant restorations have been related to fractures of the acrylic resin of the prostheses (Fig. 4).<sup>18,55,56,62</sup> Wear of acrylic occlusal surfaces increased substantially with time, according to a 15-year follow-up of fixed implant-supported prostheses in the edentulous maxilla (Fig. 5).<sup>63</sup>

In current clinical practice, porcelain has become the primary occlusal material for single-tooth and partial fixed implant restorations. It is generally agreed that ceramic occlusal surfaces provide superior esthetics and wear resistance.<sup>48</sup> Regarding full-arch fixed prostheses on implants, metal ceramic prostheses are sometimes presented in clinical reports, but in many centers acrylic resin teeth continue to be the material of choice. In removable types of implant-supported prostheses, e.g., overdentures, polymer teeth are the most common.<sup>64</sup>

## Occlusal risk factors

As in conventional prosthodontics, details of occlusion have been controversially evaluated regarding implant prostheses. In an interesting textbook on risk factors in implant dentistry,<sup>65</sup> a systematic approach to occlusal risk factors was presented. Bruxism, other oral parafunctions, fractures on natural teeth resulting from occlusal forces, and lateral occlusal contact on the implant-supported prosthesis only were listed as important risk factors. This list was mainly based on biomechanical calculations and clinical experience without strong scientific evidence. During the decade after the publication of the book, some studies on these statements were identified.

In a study of 379 patients who had worn implant restorations for many years, occlusal wear had no statistical impact on vertical peri-implant bone loss or Periotest values.<sup>66</sup> It was presupposed that occlusal wear was closely related to bruxism, and thus bruxism did not seem to be a risk factor for the examined variables. It must be emphasized, of course, that bruxism is not the only cause of tooth wear and in fact is not a major factor.<sup>67</sup> A study that started with the ambitious aim to study the influence of a number of occlusal parameters and oral parafunctions on the outcome of implant prostheses ended with the conclusion that bruxism and cantilever extensions were associated with more *technical* complications but had no significant influence on biological failures.<sup>68</sup> In a long-term study of mandibular implant-supported fixed prostheses, factors associated with occlusal loading such as bite force, tooth clenching, and cantilever length were of less importance for peri-implant bone loss than smoking and poor oral hygiene.<sup>28,69</sup> A review of literature on dental implants in patients with bruxing habits concluded that, so far, studies on bruxism and implant failure do not yield consistent results.<sup>70</sup> However, a careful approach was recommended (e.g., using more implants, longer and larger implants, stabilization splint), although admitting that these recommendations were “experience based,” not evidence based.

A literature review of nonaxial load on dental implants first stated that nonaxial forces are normal in both mastication and bruxism. There was no evidence regarding the effect of nonaxial load on implants in humans, and in two animal studies no negative effect was demonstrated. The authors concluded that the limited evidence does not demonstrate that nonaxial loading is detrimental to osseointegration.<sup>71</sup> Other risk factors related to implant occlusion discussed in the literature are crown-to-implant (C/I) ratio and the width of the occlusal table. These and other prosthodontic parameters were evaluated in a study of survival and complication rates of short implants. It was concluded that increased C/I ratio and occlusal table values did not seem to be major risk factors, with the cautious addition: “provided that force orientation and load distribution are favorable and parafunction is controlled.”<sup>72</sup>

The occlusal risk factors listed in the textbook<sup>65</sup> have not been documented as evidence based in the literature during the decade after it was published. The following conclusion in a recent consensus conference regarding occlusal loading

deserves to be quoted: “Although it has been postulated from clinical studies that occlusal forces have been associated with a loss of oral implants, a causative relationship has never been convincingly documented.”<sup>73</sup> As many clinicians still have the impression that there is some relevance in these risk factors it may be prudent to exercise caution, perform careful clinical control, and acknowledge the need for adjustments in all implant patients. When alarm signals are found, e.g., repeated loosening or fracture of abutment screws and fracture of veneering material, a careful analysis of their reason should follow with the aim to modify the situation and reduce excessive risks.<sup>65</sup>

## Different times for loading implants

The original recommendation for achieving osseointegration was to allow a healing period of 3 to 6 months before loading of the implants.<sup>27</sup> It did not take long until experiments with shorter healing periods and even immediate loading were presented. There have been various opinions on the risks and possibilities with immediate or early loading. Two Cochrane reviews have scrutinized the literature on these topics. The first review, comparing different times for placement of implants in extraction sockets, concluded that immediate implants can work and are able to shorten treatment periods. It was added that properly designed RCTs are still needed to fully evaluate the potential advantages and risks of this treatment modality because more complications and failures may occur.<sup>74</sup> The other review, which looked at different times for loading, also indicated that better designed RCTs are needed. However, it was concluded that it is possible to successfully load dental implants immediately or early after their placement in selected patients, although not all clinicians may achieve optimal results when loading the implant immediately. A high degree of primary implant stability (high value of insertion torque) seems to be one of the prerequisites for a successful immediate/early loading procedure.<sup>75</sup>

It is obvious that immediate and early loading can work, but it seems prudent to be cautious as the risk of complications is greater than when following the original strict protocol of a long healing period. Many questions remain to be answered. It is, for example, not clear in the literature whether the provisional restoration should have full occlusal contact or be infraoccluded for a period, or how long a time to wait until the definitive restoration should be placed. Two RCTs have been published after the Cochrane reviews. The first of these studies compared immediately nonocclusally loaded with early-loaded implants in partially edentulous patients followed for 14 months. It was indicated that the timing of loading did not seem to have a significant clinical impact on marginal peri-implant bone or soft tissue levels in a short-term perspective.<sup>76</sup> In the other study, no significant differences were found regarding immediate versus delayed loading of single-unit implant restorations of mandibular molars.<sup>77</sup> Even if these results seem promising, more research with longer observation periods is necessary before safer conclusions can be drawn.

## Some clinical aspects

Occlusion may seem complicated but is seldom mysterious or difficult. Complex theories of occlusion and sophisticated instruments for jaw registration should be abandoned because they have never been documented to be necessary for successful results. Occlusion can be managed successfully by using simple methods for jaw registration and different occlusal concepts. A good occlusion can be defined as synonymous with a physiological occlusion; i.e., it is comfortable for the patient, it is functioning without problems, and it is stable and does not change.

It has been recommended that occlusal contacts should be examined both on light and firm closure. On light closure there should be multiple, even, simultaneous contacts between several opposing teeth or dental restorations. On firm closure, all contacts should be maintained without movement of the mandible forward or laterally from the position after light closure. Whatever concept and instruments that have been used in the fabrication of the prostheses, the occlusion should always be checked in the mouth of the patient at insertion and at regular follow-up examinations.<sup>22,42</sup>

When checking the occlusion, it should be remembered that patients have a much lower occlusal discrimination with restorations using acrylic resin than metal ceramic teeth.<sup>47</sup> Furthermore, as the occlusal perception level is higher (i.e., the discrimination capacity is lower<sup>78</sup>) for implant-supported prostheses than for natural teeth, comments of the implant patients should be carefully considered when checking their occlusion.<sup>47</sup> It is established that the lack of periodontal receptors leads to impaired fine motor control of the mandible in implant patients.<sup>79</sup> However, early studies concluded that the functional clinical capacity of patients with implant-supported restorations was almost equal to or approaching that of dentate subjects.<sup>44,46,78</sup> A study showing that the tactile sensibility of single-tooth implants opposing natural teeth was similar to that of pairs of opposing natural teeth led to the conclusion that the implants could be integrated in the stomatognathic control circuit.<sup>80</sup> However, the results concerning occlusal sensory function of oral implants are not fully conclusive, and it seems prudent to carefully check the occlusion of implant-supported restorations with similar attention as recommended for fixed prostheses on natural teeth.<sup>22</sup>

## Discussion

Only little research has focused upon the occlusion of implant-supported restorations, and there are no RCTs comparing different occlusal designs. The studies found in the literature could thus not provide the strongest scientific evidence required for a systematic review. Studies and articles of a lower evidence level were therefore accepted and comprise the main part of this article, a method used also in other recent systematic reviews.<sup>7,8</sup> There is of course much knowledge to be acquired from the numerous studies

not fulfilling the highest scientific standard, provided that they are read with caution. However, the implication is that the results presented do not reflect the highest level of scientific evidence and may need modifications when new research results appear. Considering these limitations, the results presented should be regarded as transitory and will require modifications or amendments when new research results appear.

## Conclusions

Within the limitations in the present literature review, the following conclusions may be drawn.

- Many factors can influence implant failure and peri-implant bone loss
- Both local and general health as well as biomechanical factors may be important
- Little is known of the relative importance of such factors
- Most probably, however, occlusal factors and details of occlusion are in general of minor importance for the treatment outcome of implant restorations
- There is no evidence to recommend a specific occlusal design
- Occlusion of implant-supported prostheses can be managed successfully by using simple methods for jaw registration and different occlusal concepts

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