Implant occlusion: biomechanical considerations for implant-supported prostheses

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Clinically, natural occlusal concepts can be applied to implant prostheses. However, a natural tooth has a support design that reduces the forces to the surrounding crest of bone compared to the same region around an implant. If a clinical condition is likely to increase biomechanical stresses, dentists should implement occlusal mechanisms to decrease the stresses and develop an occlusal scheme that minimizes risk factors and allows the restoration to function in harmony with the rest of the stomatognathic system. By avoiding initial and long-term loss of crestal bone surrounding implant fixtures, implant-protected occlusion is proposed as a way to overcome mechanical stresses and strain from the oral musculature and occlusion. Implant-protected occlusion can be accomplished by increasing the surface area of implants, decreasing the width of the occlusal table, improving the force direction, and reducing the magnification of the force. By doing these things, we can minimize overload on bone-implant interfaces and implant prostheses, to maintain an implant load within the physiological limits of individualized occlusion, and ultimately provide long-term stability of implants and implant prostheses. (J Dent Sci, 3(2): 65-74, 2008)

Key words: implant occlusion, implant-supported prostheses, dental implant, progressive loading.

After osseointegration, mechanical stresses and strains beyond the physical limits of hard tissue have been suggested as the primary cause of both initial and long-term bone loss around implants1,2. If the occlusal overload is not corrected, crestal bone loss will continue until the implant fails3. Clinical reports, including animal studies, from biomechanical evaluations, bone physiology, and research support this concept. Because occlusal overload can lead to mechanical stresses on dental implants and implant prostheses, occlusion is a determining factor for implant success in the long run4,5. Determining the right occlusal scheme for implant-supported prostheses is the main issue discussed below.

According to Gartner et al.6, occlusal concepts developed from the natural dentition can be transposed to implant support systems without further modifications, because mandibular movement, velocity, and chewing patterns are the same for patients with natural teeth and implants. There are a myriad of variables in a patient population, so no one occlusal scheme can fit all implant patients. Thus, if a clinical condition is likely to increase biomechanical stresses, dentists should implement occlusal mechanisms to decrease the stresses and develop an occlusal scheme that minimizes risk factors and allows the restoration to function in harmony with the rest of the stomatognathic system. This is what we call implant-protected occlusion.

Occlusal overload is often regarded as one of the main causes for peri-implant bone loss and implant prosthesis failure, because it can cause crestal bone loss, thus increasing the anaerobic sulcus depth and peri-implant disease states if patients cannot clean well7,8. So a proper occlusal scheme is a primary
requisite for the long-term survival of implants, especially when parafunction is present.

The aims of this paper are to present the importance of implant-protected occlusion for implant longevity and to provide clinical guidelines for optimal implant occlusion based on the currently available literature.

**Differences between natural teeth and implants**

Differences between natural tooth and endosseous dental implants under occlusal loading are summarized in Table 1. The basic difference between natural teeth and endosseous dental implants is that a natural tooth has a support design that reduces the forces to the surrounding crest of bone compared to the same region around an implant. A natural tooth is suspended by the periodontal ligament (PDL) while an endosseous dental implant is in direct contact with the bone through osseointegration. The PDL absorbs shocks and distributes occlusal stresses away along the axis of natural teeth. However, an endosseous dental implant connected to the bone by osseointegration lacks those advantages of the PDL.

Teeth in natural dentition are retained by periodontal tissues that are uniquely innervated and structured. When natural teeth are lost, both occlusion and attachment with its proprioceptive feedback mechanism are lost. When loaded, the movement patterns of natural teeth begin with the primary phase of periodontal compliance that is primarily non-linear and complex, followed by the secondary movement phase which occurs with engagement of the alveolar bone. In contrast, the movement of an implant under loading is dependent on linear and elastic deformation of the bone. The PDL in a natural tooth can produce differences in force adaptation compared with osseointegrated implants due to its shock-absorbing and stress-distributing functions.

Non-vertical forces on natural teeth during function affect only the teeth involved and are usually tolerated, whereas in implants, the effect involves the crest of the bone, which is usually traumatic to the supporting structures. According to Parfitt, a lateral force on a healthy natural tooth is rapidly dissipated away from the crest of bone toward the apex of the tooth due to the natural tooth rapidly moving 56~108 µm and rotating around the apical 1/3 of the root. On the other hand, movement of an implant occurs gradually, reaching up to about 10~50 µm under a similar lateral force. So greater forces are concentrated on the crest of the surrounding bone of dental implants.

**Table 1. Differences between natural teeth and implants**

<table>
<thead>
<tr>
<th></th>
<th>Natural teeth</th>
<th>Implants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surrounding tissue</strong></td>
<td>Periodontal ligament (PDL)</td>
<td>Osseointegration</td>
</tr>
<tr>
<td><strong>Malocclusion</strong></td>
<td>May be uneventful for years</td>
<td>Crestal bone loss</td>
</tr>
<tr>
<td><strong>Non-vertical forces</strong></td>
<td>Relatively tolerated</td>
<td>Traumatic to supporting bone</td>
</tr>
<tr>
<td><strong>Loading-bearing characteristics</strong></td>
<td>Shock-absorbing function</td>
<td>Stress concentrated at crestal bone</td>
</tr>
<tr>
<td><strong>Movement patterns</strong></td>
<td>Primary: immediate movement (non-linear and complex)</td>
<td>Gradual movement (linear and elastic)</td>
</tr>
<tr>
<td><strong>Fulcrum to lateral forces</strong></td>
<td>Apical 1/3 of root</td>
<td>Crestal bone</td>
</tr>
<tr>
<td><strong>Lateral movement</strong></td>
<td>56~108 µm</td>
<td>10~50 µm</td>
</tr>
<tr>
<td><strong>Apical movement</strong></td>
<td>25~100 µm</td>
<td>3~5 µm</td>
</tr>
<tr>
<td><strong>Signs of overloading</strong></td>
<td>PDL thickening, mobility, wear facets, fremitus, pain</td>
<td>Screw loosening or fracture, abutment or prosthesis fracture, bone loss, implant fracture</td>
</tr>
<tr>
<td><strong>Tactile sensitivity</strong></td>
<td>High (proprioceptive feedback mechanism)</td>
<td>Low (osseoperception)</td>
</tr>
</tbody>
</table>

Modified from Kim et al.47
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in the absence of rotation\textsuperscript{16}. Under similar lateral loads, an implant does not pivot as much as a tooth toward the apex, but instead concentrates greater forces at the crest of the surrounding bone. Therefore, if an initial load of equal magnitude and direction is placed on both an implant and natural tooth, the implant must be protected.

Malocclusion of natural teeth may be uneventful for years. Malocclusion on an implants evokes a traumatic response and involves the crest of the surrounding bone. Richter’s study\textsuperscript{18} reported that a transverse load and clenching at centric contacts resulted in the highest stresses in the crestal bone of dental implants. Misch\textsuperscript{19} and Schulte\textsuperscript{8} suggested gradient loading to accommodate the disadvantageous kinetics associated with dental implants in patients with a poor bone quality condition.

In natural teeth, proprioception gives the neuromuscular system control during function. This makes it possible for a person to avoid prematurities and interferences, and to establish a stable habitual occlusion away from a centric relation. With dental implants, no such feedback signal system is present, and the mandible’s function will end its chewing stroke in the most favorable kinesiologic position, which is very close to a centric relation. If cusps interfere or prematurities exist as the mandible returns to this position, crest bone loss will occur. The presence or absence of the PDL’s function makes a remarkable difference in detecting the early phase of occlusal forces between teeth and implants\textsuperscript{2}. Because periodontal mechanoreceptors in natural teeth provide proprioception and early detection of occlusal forces and interferences, the bite forces used in mastication and parafunction are not as strong due to fine motor control of the mandible. Trulsson et al\textsuperscript{20} also reported that implant denture patients split a peanut with a force 4-fold greater than that of the natural dentition group and pointed out that a lack of proprioception can lead to a heavier bite force in implant patients. Mericske-Stern et al\textsuperscript{14} measured the oral tactile sensibility with test steel foil. The detection threshold of minimal pressure was significantly higher with implants than with natural teeth (3.2 vs. 2.6 steel foil sheets). Jacobs and van Steenberghe\textsuperscript{21,22} evaluated occlusal awareness and found that interference perceptions of natural teeth, implants with opposing teeth, and implants opposing implants were approximately 20, 48, and 64 µm, respectively. Hammerle et al\textsuperscript{23} also concluded that the mean threshold value of tactile perception for implants (100.6 g) was 9-fold higher than that of natural teeth (11.5 g).

Clinical evidence of occlusal trauma on teeth includes an overall thickening of the periodontal membrane, tooth mobility, and increased radiopacity and thickness of the cribriform plate around a tooth, as observed on radiographs and not just localized at the crest. A tooth can show clinical signs of increased stresses such as enamel wear facets, cervical abfraction, fremitus, and pain. When implants are subjected to repeated excessive occlusal loads, no generalized radiographic signs are apparent around an implant, except at the crestal region, which demonstrates bone loss but may be misdiagnosed as peri-implant disease due to bacteria. Implant components rarely show clinical signs other than fatigue fractures (screw loosening or fracture, abutment or prostheses fracture, and implant fracture)\textsuperscript{11-13}.

Dentists can replace a natural tooth with an artificial one but not its attachment, which presents a new problem, and it seems logical that some changes must be made. The above differences necessitate consideration of occlusion for dental implants as a special problem with different requirements if they are to function efficiently with the least amount of trauma to supporting tissues. From biophysiological differences between a natural tooth and endosseous dental implant, we concluded that osseointegrated implants without periodontal receptors would be more susceptible to occlusal overloading. Because the load-sharing ability, adaptation to occlusal forces, and mechanoperception are significantly reduced in dental implants, there are differences in occlusal considerations between natural teeth and implants.

Overloading risk factors for implant prostheses

Cantilevers

Cantilevers with less-favorable crown/implant ratios can increase the possibility of overloading, possibly resulting in peri-implant bone loss and prosthesis failure\textsuperscript{28,29}. In terms of cantilever length, a clinical study demonstrated that long cantilevers (≥ 15 mm) induced more implant-prostheses failures compared to cantilevers < 15 mm long\textsuperscript{28}. Duyck et al\textsuperscript{27} also reported that when a biting force was applied to a distal cantilever, the highest axial forces and bending
movements were recorded on the distal implants, which were more pronounced in prostheses supported by only 3 implants, compared to prostheses with 5 or 6 implants. The above study indicated that a shorter cantilever length is more favorable for the success of implant-supported prostheses, particularly for prostheses with fewer implants.

The occlusal contact position can determine the direction of force which may result in overloading of supporting implants, especially during parafunction. An occlusal contact on a buccal cusp which is cantilevered from the implant body, angled buccal cusp, or marginal ridge contact may also be damaging. After a period of time, the distribution of occlusal forces changes so that there is greater force over the cantilever. Clinicians must keep in mind the potential anterior, as well as posterior, cantilever that can be created. Cantilevers can cause screw loosening and/or prosthetic screw or abutment screw breakage and should be eliminated. Therefore, periodic evaluation of occlusion is necessary.

Parafunctional activity

The etiology of tooth loss is a good way to evaluate the occlusal state of patients. Both the force intensity and parafunctional habits can have a considerable negative effect on the stability of implant components. Many studies have reported that parafunctional activities and improper occlusal designs are correlated with implant bone loss and failures. Falk et al. proposed that the numbers and distribution of occlusal contacts had major influences on the force distribution between a cantilevered segment and the implant-supported area, especially with cantilevered units. Naert et al. reported that overloading from parafunctional habits such as clenching or bruxism seemed to be the most probable cause of implant failure and marginal bone loss. They suggested that shorter cantilevers, proper location of the fixtures along the arch, a maximum fixture length, and night-guard protection should be prerequisites to avoid parafunctions or overloading of implants in these patients. Quirynen et al. also reported that excessive marginal bone loss and implant loss were found in patients with a lack of anterior contacts, the presence of parafunctional activities, and full-fixed implant-supported prostheses in both jaws. Rangert et al. analyzed 39 fractured implant cases and found 35 (90%) of cases had occurred in the posterior area while 30 (77%) of the prostheses were supported by 1 or 2 implants with a cantilever associated with heavy occlusal forces such as bruxism. They concluded that an in-line placement of an implant, a cantilever, and bruxism or heavy occlusal forces may increase risks of bending overload when replacing missing posterior teeth with 1 or 2 implants.

Premature contacts

Premature contacts are defined as occlusal contacts that divert the mandible from a normal path of closure, interfere with normal, smooth, gliding mandibular movement, and/or deflect the position of the condyle, teeth, or prosthesis. Several animal studies demonstrated that excessive lateral forces from premature occlusal contact can cause excessive marginal bone loss or even osseointegration failure. Isidor reported that excessive occlusal overloading can cause severe crestal bone resorption and loss of osseointegration. Miyata et al. studied monkeys with different heights of premature contact, under inflammatory and non-inflammatory conditions. Their results suggested that there is a critical height of premature contact on implant prostheses for crestal bone loss, especially under peri-implantitis. Lateral premature occlusal loads to the implant crestal region are further magnified when crown height is increased or when present on the cantilevered portion of the prosthesis. Therefore we speculated that occlusal overload from excessive lateral forces may act as one of the factors causing marginal bone loss and implant failure.

Bone quality

In human studies, higher rates of implant failure were reported in bone of poor quality. Occlusal overload on poor-quality bone can be a crucial factor in implant success and longevity at both the surgical and prosthetic stages. Engquist et al. reported that higher implant failures in maxillary overdentures were attributed to poor bone quality of the maxilla. Jaffin and Berman evaluated 90% of 1054 Branemark implants placed in type I, II, and III bone and 10% of fixtures placed in type IV bone and reported that only 3% of fixtures in type I, II, and III bone were lost compared to 35% of fixtures in type IV bone which failed during second-stage surgery. They pointed out
that the quality of bone was the greatest determinant of fixture loss.

In addition to poor bone quality, unfavorable force direction and concentration may increase failure rates of implants. Becktor et al. evaluated the influence of mandibular dentition on maxillary implant failure and suggested that efforts should be made to build up a favorable occlusion with special attention to a broad distribution of occlusal contacts. Esposito et al. characterized the cellular composition of the soft tissues surrounding consecutively retrieved late failures of Branemark implants and suggested that ongoing infection was unlikely to be an etiological factor in late failures of implants. They thought that the combination of poor bone quality and overloading were the causes of late implant failure.

Occlusal considerations for implant-supported prostheses

It is generally accepted that all concepts of occlusion developed from natural dentition can be transposed to implant-supported systems without modification. Three occlusal concepts, balance, group function, and mutually protected occlusion, have been established through clinical trials and conceptual theories. These concepts may produce maximum intercuspation (MIP) during habitual and/or centric occlusion. These occlusal concepts (i.e., balance, group function, and mutually protected occlusion) have been successfully adopted with modifications for implant-supported prostheses. Wennerberg et al. observed that no occlusal factors in mandibular implant-supported prostheses opposing a complete denture in the maxillary influenced patient satisfaction or treatment outcomes. They concluded that occlusal schemes may be of limited importance in patient satisfaction and treatment outcomes recorded clinically and radiographically at follow-up examinations during implant prosthesis rehabilitation. So developing tooth morphology to reduce overloading risk factors (biomechanical risk factors) in implant prostheses is an important factor to consider when constructing implant prostheses.

Implant-protected occlusion

Implant-protected occlusion, as originally developed by Misch, refers to an occlusal plan that is often unique and specifically designed to restore an endosseous implant, by providing an environment for improved clinical longevity of both the implant and prosthesis. Misch and Bidez published the biomechanical rationale for this concept after longterm evaluation and proposed implant-protected occlusion by reducing the occlusal forces on implant prostheses to protect the implants. Therefore several modifications from conventional occlusal concepts have been proposed to reduce overloading on implant prostheses. Specific occlusal factors that may influence crestal bone loss include:

1. Provision of load-sharing occlusal contacts;
2. Modifications of the occlusal table and anatomy;
3. Correction of the load direction;
4. Increase in implant surface areas; and
5. Elimination or reduction of occlusal contacts in implants with unfavorable biomechanics.

Those modifications must still follow the basic principles of implant occlusion which include (1) anterior guidance whenever possible, (2) bilateral stability in centric (habitual) occlusion, (3) wide freedom in centric (habitual) occlusion, (4) evenly distributed occlusal contacts and forces, (5) no interferences between the retruded position and centric (habitual) position, and (6) smooth and even lateral excursive movements without working/non-working interferences.

Occlusal contacts without prematurity

Because implant and tooth movements are not similar, concerns about occlusal load have been expressed when joining implants to natural teeth. When considering occlusion for implant-supported prostheses, precautions must be taken in terms of the biophysiological differences between natural teeth and osseous implants. Avoiding occlusal prematurity between maximum intercuspation and centric relation occlusion should be noted especially with implant-supported prostheses, because “non-mobile” implants bear the total load of the prosthesis when joined with “mobile” natural teeth. When we perform oral rehabilitation and occlusal adjustment between implants and natural teeth, the occlusal design may be ideal, but premature occlusal contacts on the implants may still occur because the natural teeth may sustain sudden movement away from the centric during function (Table 2). Occlusal contact with centric occlusion on implant prostheses when natural teeth are adjacent requires a reduced initial mechanical load on
the implants. Light force and thin articulating paper (<25 µm) are first used to evaluate the centric relation of occlusal contact. The implant crown is relieved, which places heavier contact on the adjacent natural tooth. A greater occlusal force is then applied to the articulating paper, with equal contact regions established on the implant-supported crowns and natural teeth. A tooth might not return to its original position for several hours after application of a heavy occlusal force. As a consequence, light forces on adjacent natural teeth are first equilibrated.

Occlusal adjustment of the opposing dentition with an implant or natural tooth should follow the implant-protected occlusion concept which protects the implant-bone crest region, and covers not only light force occlusal equilibration but also heavy occlusal loadings. That is to say that occlusal adjustment of implants and teeth in the opposing arch should compensate for primary tooth movement. In most situations, the occlusal adjustment of a heavy bite force is underestimated or neglected by some dentists, especially those who feel that early crestal bone loss is primarily due to biological width conditions. All excursions of implant-protected occlusions opposing fixed prostheses or natural teeth should disocclude the posterior component.

Excursion are evaluated after the centric occlusion has been corrected. Many occlusal schemes in which natural teeth oppose each other suggest that the anterior teeth disocclude the posterior teeth in excursions. If healthy anterior teeth and/or natural canines are present, the occlusion allows the teeth to distribute horizontal (lateral) loads in excursions, while the posterior teeth disocclude any excursion.

**Anterior guidance**

As previously discussed, the lateral movement of healthy anterior teeth is significantly larger than implant movements. Therefore, the anterior teeth have greater apical and lateral movements compared to implants, and differences in lateral movement are greater, thus causing occlusal adjustment. Many occlusal schemes have suggested using the anterior teeth to disocclude the posterior teeth during eccentric excursion. Anterior bite force measurements and electromyographic studies also reported that the stomatognathic system elicits significantly less force when the posterior segments are not in contact in the lateral mandibular position. According to Weinberg and Kruger, with every 10° change in the angle of disclusion, there is a 30% difference in load. They suggested that the anterior guidance of implant-supported prostheses should be as shallow as possible to avoid greater forces on the anterior implants by steeper incisal guiding angles.

**Cusp inclination**

Cusp inclination has been found to produce a high level of torque and represents the most significant clinical finding. For every 10° increase in cusp inclination, there is an approximately 30% increase in torque. Weinberg and Kruger evaluated the torque of a gold screw, abutment screw, and implant and concluded that cuspal inclination produces the most torque, followed by maxillary horizontal implant offset, while implant inclination and apical implant offset produce minimal torque. Kaukinen et al. determined the difference of the force transmission between 33° and 0° cusps. The mean initial breakage force of 33°-cusped specimens was 3.846 kg, while the corresponding value of the 0° cuspless occlusal designed specimens was 1.938 kg. So they suggested that the cusp inclination affects the magnitude of forces transmitted to implanted prostheses. Weinberg also claimed that cusp inclination is 1 of the most significant factors in producing bending moments. Because the angle of force to the implanted body may be influenced by

<table>
<thead>
<tr>
<th>Vertical direction</th>
<th>Natural teeth</th>
<th>Implants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial tooth movement</td>
<td>8–28</td>
<td>0</td>
</tr>
<tr>
<td>Secondary tooth movement</td>
<td>3–5</td>
<td>3–5</td>
</tr>
</tbody>
</table>

**Table 2. Movement patterns of natural teeth and implant movement (µm) under loading (1.36~2.27 kg)**
cusp inclination, a reduction in cusp inclination can decrease the resultant bending moment with a lever-arm reduction and improvement of the axial loading force. Therefore a reduced cusp inclination, shallow occlusal anatomy, and wide grooves and fossae may be beneficial when constructing implanted prostheses due to the axial loading induced. It is especially critical when the intensity and duration of the force increase.

**Occlusal table width**

Typically, a 30%–40% reduction in the occlusal table in a molar region has been suggested because any dimension larger than the implant diameter can cause cantilever effects and eventual bending moments in single-implant prostheses. A narrow occlusal table reduces the chance of offset loading and increases axial loading, which eventually can decrease the bending moment. Misch also described how a narrow occlusal table can improve oral hygiene and reduce the risk of porcelain fracture. In addition, the posterior maxillary region with buccal bone resorption may cause palatal placement of implants compared with the position of natural teeth if bone augmentation is not performed. A normal occlusal contour in these conditions may create a buccal cantilever with a poor biomechanical environment. We can use cross-bite occlusion in these conditions to avoid the buccal cantilever and increase the axial loading.

**Maxillary anterior teeth**

From a biomechanical perspective, an implant-restored anterior maxilla is often the weakest section compared with other region of the mouth. Compromised anatomical conditions include narrow ridges and the need for narrow implants, the use of facial cantilevers, oblique centric contacts, lateral forces in excursion, reduced bone density, the absence of a thick cortical plate at the crest, and accelerated bone loss in the incisor region often resulting in instability when placing central and lateral incisor implants without substantial augmentation procedures. Recently, Saab et al. studied the abutment angulation in anterior maxillary implants using 2-dimensional finite element models and found that the greatest strain was produced on cancellous bone, adjacent to the 3 most apical microthreads on the palatal side of the implant where tensile forces were created. The model predicted a 15% higher maximum bone strain for a straight abutment compared to an angled abutment. The results of that study suggested that using an angled abutment, compared to a straight abutment, may decrease the strain on the bone when restoring implants in the anterior maxilla.

According to Misch’s statement, the compromised mechanics of the premaxilla require special attention in establishing an implant-protected occlusion. He suggested that negative factors should be reduced by increasing the number and diameter of implants (which often requires bone augmentation) while disoccluding the posterior teeth in each lateral excursion. As a result, at least 3 implants are usually required to replace the 6 anterior teeth, and 2 of these should be in canine positions. When force factors are greater than usual, at least 4 implants are suggested. The 3 or 4 implants should be splinted together and should share any lateral forces during excursions.

**Implant-bone contact surfaces**

The narrower the implant body, the greater is the influence of the occlusal table width and offset loads. Wider root-form implants have a broader range for vertical occlusal contacts and transmit less force at the perimucosal site with offset loads compared to narrow root-form or plate-form implants. Therefore, the width of the occlusal table of implant-protected occlusion is directly related to the width of the implant body.

Mechanical stress can be defined as the force magnitude divided by the cross-sectional area over which that force is applied. In natural dentition, the anterior teeth have small contact areas due to the light forces sustained, while posterior teeth exhibit larger surface areas on account of the maximum loading. These principles can also be applied to implant cases. When implants with a decreased surface area are subjected to angled or increased loads, the mechanical stresses can be minimized by placing an additional implant or by splinting the implant together to increase the surface of support. To compensate for the increased magnitude of a force, the direction or duration (e.g., parafunction), ridge augmentation to improve implant placement, a reduced crown height, or an increased diameter and number of implants can be utilized. If the anatomical conditions limit those choices, the prosthesis type may need to be modified from a fixed prosthesis to a removable one.
The concept of progressive bone loading

Bone density is the most critical factor in determining the amount of healing time between first- and second-stage surgery and the appointments for prosthesis restoration. Jaffin and Berman\textsuperscript{36} and Friberg \textit{et al.}\textsuperscript{59} reported early implant failures of as great as 35%, especially in cases with poor bone quality, after successful surgical survival of implants. Premature occlusal overload can cause poor osseointegration, even in dense mandibular bone (Figure 1). Misch\textsuperscript{37,60} first proposed the concept of progressive bone loading during prosthetic reconstruction to permit development time for load-bearing bone at the bone-to-implant interface and provide bone with adaptability to loading via a gradual increase in loading. Then he modified this concept by incorporating time intervals (from 3 to 6 months), diet (avoid chewing with a soft diet, then harder food), occlusion (gradually intensify the occlusal contacts during prosthesis fabrication), prosthesis design, and occlusal materials (from resin to metal to porcelain) for poor bone quality conditions\textsuperscript{41}. Appleton \textit{et al.}\textsuperscript{62,63} found that progressively loaded implants preserved the crestal bone height and improved the peri-implant bone density around implants. Their findings suggest that an extended healing time and progressive bone loading may be needed in patients with poor bone quality.

CONCLUSIONS

Because osseointegrated implants are ankylosed to the surrounding bone without the periodontal ligament, they lack mechanoreceptors and a shock-absorbing function. Occlusal overload is often regarded as one of the main causes for peri-implant bone loss and implant/implant prosthesis failure. Many clinical complications such as prosthesis fracture, screw loosening or fracture, implant fracture, continuing marginal bone loss, and implant loss may be attributed to implant overload. These complications can be prevented by application of biomechanical principles such as the passive fitting of prostheses, reducing the cantilever length, narrowing the buccolingual / mesiodistal dimensions of the prosthesis, reducing cusp inclination, eliminating excursive contacts, and centering occlusal contacts. Sometimes, the type of prosthesis can be changed and more implants added to prevent potential biomechanical complications. In patients with poor bone quality, the concept of progressive bone loading can be used to permit development time for load-bearing bone at bone-to-implant interfaces and provide bone with adaptability to loading via a gradual increase in loading.

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