INTRODUCTION
Fortunately, implants and implant-supported prostheses continue to demonstrate 90% to 95% 5-year survival rates. Despite this fact, occlusal forces applied to an implant prosthesis have been shown to be a potentially destructive factor in shortening the longevity of any implant prosthesis. Implant deosseointegration and material failures have been attributed to excessive occlusal loading to dental implants and the prosthesis. However, the role of occlusion in the loss of bone following placement of an implant prosthesis is still a debatable topic.

This article will discuss occlusal stress in regards to crestal peri-implant bone loss while reviewing the current concepts of occlusion to possibly employ when dental implants are restored. Three clinical cases will be presented that demonstrate the currently available methods to control the magnitude and time duration that aberrant occlusal forces are placed on implant prostheses.

Literature Review
Several studies have explored both the microbiological factors and occlusal overload in relation to implant failure. Esposito et al suggested that excessive surgical trauma in addition to an impaired healing ability, premature loading, and infection were the most common causes of early implant loss. They suggested that progressive chronic marginal infection (peri-implantitis) and occlusal overload in conjunction with host characteristics may be a primary reason for late failures. Heydenrijk et al concluded from significant data that bacteria cause the disease (peri-implantitis), while the individual's genetic makeup and environmental influences determine the severity of the disease. Others have concluded that implant failure is multifactorial, and often has multiple causative agents.

Excessive loading, premature loading, or incorrectly vectored forces can place undesirable stresses on an implant restoration, ultimately resulting in failure. Misch reported that improper occlusion with increased localized forces frequently results in prosthesis complications that can involve the implant and the supportive bone (loosening of the implant and reduction in crestal bone height). He stated that appropriate timing and directional force loading on an implant-supported prosthesis aids in a desirable and physiologic outcome.

The association between crestal bone loss and excessive occlusal forces does not exclude the importance of other factors, such as microgaps between the implant and the abutment, and bacterial infection. Several investigators feel that bacterial infection is necessary for implant failure, although occlusion is recognized as a co-factor. Saadoun et al described how excessive occlusal forces on implants when combined with microbial infection can cause bone loss and implant failure.

Various studies have identified how excessive occlusal force is directly related to bone loss, whereby occlusal forces transmitted to the bone-implant interface through the implant prosthesis can strain the interface directly. Quirynen et al evaluated 93 patients with various implant-retained restorations and concluded the amount of crestal bone loss was directly associated with

continued on page 114
occlusal loading. In a clinical report by Leung et al., implant bone loss was associated with prosthesis hyperocclusion. Following removal of the prosthesis, the bony defect resolved, and when the prosthesis was replaced with an appropriate occlusal environment, bone height remained stable throughout time. This report described how an association exists between excessive occlusal forces and bone loss, and suggested that the bone loss may reverse when the occlusion is corrected.

An example of bone loss reversal was demonstrated by Stevens using time-delayed occlusal loading. By adjusting the timing order on a distal extension implant prosthesis that was losing bone, such that the implant occlusal contacts occurred later than the adjacent natural teeth, the lost bone was regenerated.

Occlusal Management
When adjusting occlusion, clinicians typically have 2 tools at their disposal—articulating paper and patient feedback—both of which have significant limitations. Articulating paper marks on teeth demonstrate forensically that contact occurred, such that when (and if) ink transfer occurs, the paper shows the location of the contact. However, the marks do not tell the clinician when the contact occurred, how long the contact was present, or the contact's degree of applied occlusal force. Unfortunately, the size of the ink transfer is often misinterpreted. It has been advocated that a large contact area equals a heavy occlusal force, but it is important to emphasize that when considering the size of a contact, a large mark may in fact disperse the force better than do smaller contacts.

Patient feedback is a subjective and often unreliable method for determining occlusal balance. Because implants do not have a periodontal ligament, and therefore do not have proprioceptors and mechanoreceptors, human perception of occlusal force and contact timing is diminished. A 1995 study by Hämmert et al. indicated that a patient's perception of occlusal contact force on an implant-supported prosthesis is one eighth as reliable than when perceiving forces on natural teeth.

The proper occlusal adjustment of implant prostheses is complicated when there is a mixed implant-natural tooth occlusal scheme. Without

continued from page 112

Technology to Control Excessive...

continued on page 116
Technology to Control Excessive...  
continued from page 114

periodontal ligament fibers, implants demonstrate minimal depressability in the alveolar bone when compared to a healthy tooth that experiences far more vertical depression. Parritti found that nonmobile posterior teeth depress approximately 28 µm vertically, and can move 56 to 75 µm laterally. In contrast, Sekine et al. found that well-integrated endosteal implants depress vertically 5 µm, and move laterally 12 to 66 µm.

Since the implant-retained prosthesis moves less than natural teeth, simultaneous occlusal loading of natural teeth and an implant prosthesis within the same quadrant may result in the implant prosthesis bearing more of the occlusal load than the more depressible natural teeth. This load-bearing difference has led Misch and Bides to both suggest that increased force can be placed on an implant prosthesis, the clinician nor the patient recognizes that decreased force can be placed on an implant prosthesis. Hämmerle et al. reported that mobile posterior teeth are surrounded by conductive ink that together can discern 256 differing levels of applied occlusal force. The recording handle scans the sensels and digitizes their voltage outputs at a rate of 100 to 300 frames/second. This allows measurement of not only the relative force at each contact point within the arch, but also the onset and duration of each contact, with 0.10- to 0.03-second resolution. Consequently, T-Scan recordings provide the restorative dentist with a precise means of determining the time order of the relative contact forces as they evolve sequentially on an implant prosthesis and the surrounding natural teeth. The data can be stored on a computer’s hard drive for subsequent analysis in a video format referred to as a “movie.”

The...occlusal adjustment of implant prosthesis is complicated when there is a mixed implant-natural tooth occlusal scheme.

Implants and teeth are kept independent of one another, with the implants placed into hypo-occlusion. Additionally, Hämmerle et al. reported the patient may not be able to recognize that increased force can be placed on an implant prosthesis. When neither the clinician nor the patient recognizes excessive occlusal forces on implant restorations, the degree of osseointegration, the crestal bone height stability, and the long-term prosthesis success can all be impacted.

In an effort to prevent excessive forces from being applied to an implant prosthesis, Kerstein and Kirveskari proposed that a quantifiable time (and force) delay be implemented occlusally, to allow the natural teeth to occlude in advance of the implant prosthesis. The natural teeth would then undergo depression into the periodontal ligament prior to the time occlusal loading on the implant prosthesis would initiate. With this occlusal scheme, the applied force would then be absorbed by both the natural teeth and the implant prosthesis. However, it is important that the time delay be short enough so that the implant prosthesis is actually functional, rather than become a highly refined, aesthetic space maintainer.

Achieving a quantifiable time delay requires employing occlusal force and timing measurement techn-

Figure 11. Clinical view of an implant prosthesis replacing tooth No. 3. Note that the implant prosthesis is in the terminal position, making cradling impossible.

Figure 12. Radiograph of 5.2 mm diameter, 10 mm Legacy 3 implant and prosthesis for tooth No. 3.

Figure 13. Still frame of the T-Scan movie. Note the teeth anterior to the implant prosthesis begin to absorb the occlusal force before the implant prosthesis.

Figure 14. Advancing the movie 0.02 seconds shows an increase in force but in a “stepped” fashion with the implant still being subjected to low force.

Figure 15. Advancing the movie 0.10 seconds further shows that the force continues to be greater on the natural teeth but the implant is indeed functional. The stepped appearance of force application is evident.

The first case demonstrates the high potential of creating a “no-occlusion” scheme when clinicians attempt to create hypo-occlusion as described by Misch and Bides and Kim et al. This patient presented with an endodontically treated tooth No. 19 that experienced a subsequent root fracture. The tooth was extracted, and following appropriate healing, the No. 19 site was implanted with a 5.2-mm diameter, 11.5-mm length Legacy 3 (Implant Direct) implant. The cover screw and 2-mm extender included with the Legacy 3 implant were utilized as the healing abutment during integration, after which prosthetic impressions were completed and seated (Figure 2).

A single T-Scan movie frame is shown in Figure 3, where the desktop’s left side is a representation of the maxillary arch, known as the 2-D Force View, which displays all the relative forces applied to the teeth and the implant prosthesis, with blue representing low relative force and red/pink representing high relative force. The desktop’s right side shows the same color-coded data in a 3-D columnar view. This data then can be interpreted and applied to either the maxillary or mandibular teeth/prostheses to make measured occlusal force corrections. Note the right side of the arch demonstrates 71% of total force with only 29% on the left side, whereas 50% right/50% left is desirable. The low total left side force results from the
implant prosthesis having no occlusal contact. Although this may extend the life of the prosthesis, this author prefers the prosthesis to be functional.

**Case 2**

The second case also details an implant prosthesis replacing tooth No. 19 (Figures 4 and 5). Despite the patient being a smoker with potential complications, the implant option was the patient’s desire. In this case, a 4.7-mm diameter, 10-mm length Legacy 3 implant was placed. Following crown cementation, a T-Scan movie frame of the patient at 42.66% of total force shows most of that force is on the implant prosthesis (Figure 6). Of more concern is that force is on the implant prosthetic component in the patient’s right mandibular second molar.

**DISCUSSION**

Implants respond to occlusal forces differently than natural teeth. Because the cushioning effect of the periodontal ligament is absent with implants, the occlusal forces are directly transmitted to the bone surrounding the implants. According to Misch et al., methods to decrease stress on an implant prosthesis are appropriate and warranted, and the restorative dentist is most capable to address this condition. Chapman suggested that establishing an appropriate occlusion plays a vital role in the success of both the implant and the attached prosthesis. Occlusal management with the T-Scan System can be a valuable aid in controlling occlusal force and contact timing problems that stress implant prostheses. Use of traditional nondigital occlusal indicators (patient feedback, articulating paper, shim stock, silicone bite imprints, occlusal wax) may be unreliable and cannot be quantitatively analyzed. Excessive force left in place, due to incomplete equilibration, may compromise the implant; whereas lack of occlusion, perhaps due to excessive equilibration, may reduce the implant prosthesis into a nonfunctioning space maintainer. When both the force and timing of occlusal contacts are measurably managed, an implant prosthesis can become a long-term functioning component in the patient’s occlusal scheme.

**CLOSING COMMENTS**

Elimination of excessive forces on implants has been deemed one of the important factors in the long-term success of implant-borne prostheses. The T-Scan technology is an invaluable tool for creating appropriate occlusal contacts following implant placement and restoration. Alternately, articulating paper does not provide any indication of contact force or time sequencing. And, patient perception is too subjective to predictably control implant prosthesis occlusal force overload, such that adjustments made to an implant prosthesis that depend on patient “feel” may compromise the longevity of both the implant and prosthesis itself. Digital occlusal force and timing measurements afforded by the T-Scan system can help the clinician ensure that implant prosthesis insertion occlusal adjustments will create a preservative occlusal scheme, rather than a subjectively installed, potentially destructive one.

**References**

2. Kohali D. Complications in the tissue integrated prostheses components: clinical and mechani-

7. Rosenbarg ES, Torosian AJ Slots J. Microbial dif-

11. Saadoun AP, LeGall M, Kruchke M. Microbiol-

12. Quirynen M, Naert I, van Steenbergen D. Fixure design and overload influence marginal bone loss and fixture success in the Branemark sys-
14. Stevens CJ. Computerized occlusal implant man-

18. Misch CE, Bides MW. Implant-protected occlu-
19. Kim Y, Oh TJ, Misch CE, et al. Occlusal consider-
26. González Sequeros O, Garrido García VC, Garcia Cartagena A. Study of occlusal contact variabil-
27. Garcia Cartagena A, Gonzalez Sequeros O, Garrido Garcia VC. Analysis of two methods for occlusal contact registration with the T-Scan sys-
28. Garrido Garcia VC, Garcia Cartagena A, Gonzalez Sequeros O. Evaluation of occlusal contacts in maximum interincisal occlusion using the T-Scan sys-

---

**Dr. Stevens**, a graduate of the Marquette University School of Dentistry in Milwaukee, WI, is a member of the ADA, the Wisconsin Dental Association, and the Dane County Dental Society. He was also a fellow of the International College of Cranio-Mandibular Orthopedics and a Diplomate in the American Academy of Pain Management. He co-founded the Multi-Disciplinary Pain Clinic at the Medical College of Wisconsin and maintains a teaching center, the Center for Advanced Studies of Functional and Restorative Esthetics, and a general dental practice in Sun Prairie, Wis. He is an international speaker on the subjects of smile enhancement, principles of occlusion, full-mouth restoration, and diagnosis and treatment of temporomandibular disorders (TMD). He has been an active lecturer for more than 2 decades and has spoken thousands of hours of dental education for dentists, including physicians, chiropractors, and physical therapists. Since 1991, he has been instructing doctors and their teams on the use of computer-enhanced diagnostic equipment in dentistry. Widely accepted applications for these instruments have been found in diagnosis and treatment of TMD, 3-D mandibular repositioning, principles of occlusion, and occlusal management processes. He can be reached via email at ojs@thebestsmiles.net.

**Disclosure:** Dr. Stevens is a lecturer for Tekscan and Implant Direct.

**IMPLANTS**

**Closing Comments**

Elimination of excessive forces on implants has been deemed one of the important factors in the long-term success of implant-borne prostheses. The T-Scan technology is an invaluable tool for creating appropriate occlusal contacts following implant placement and restoration. Alternatively, articulating paper does not provide any indication of contact force or time sequencing. And, patient perception is too subjective to predictably control implant prosthesis occlusal force overload, such that adjustments made to an implant prosthesis that depend on patient “feel” may compromise the longevity of both the implant and prosthesis itself. Digital occlusal force and timing measurements afforded by the T-Scan system can help the clinician ensure that implant prosthesis insertion occlusal adjustments will create a preservative occlusal scheme, rather than a subjectively installed, potentially destructive one. Use of traditional nondigital occlusal indicators may be unreliable, and cannot be quantitatively analyzed.