Technology to Control Excessive Occlusal Contact Force

Enhancing Implant Restoration Longevity

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INTRODUCTION

Fortunately, implants and implant-supported prostheses continue to demonstrate 90% to 95% 5-year survival rates.[1] 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.[2,3] However, the role of occlusion in the loss of bone following placement of an implant prosthesis is still a debatable topic.[4]

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[5] 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[6] 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[7-9] 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[10] 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[10] 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 cofactor.[4-7] Saadoun et al[11] described how excessive occlusal forces on implants when combined with microbial infection can cause bone loss and implant failure.

Various studies[12,13] 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[12] evaluated 93 patients with various implant-retained restorations and concluded the amount of crestal bone loss was directly associated with

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Figure 1. The T-Scan system (Tekscan) with the Mylar sensor to record both force and time of contact.

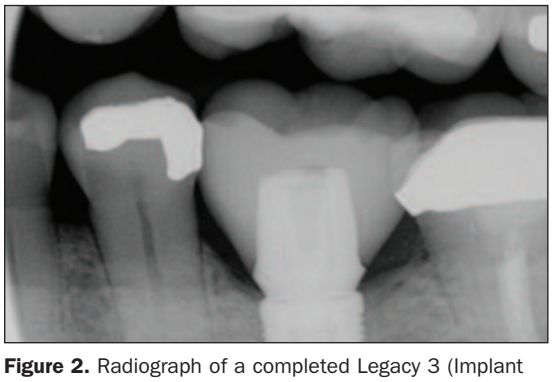

Figure 2. Radiograph of a completed Legacy 3 (Implant Direct) implant and prosthesis for tooth No. 19.

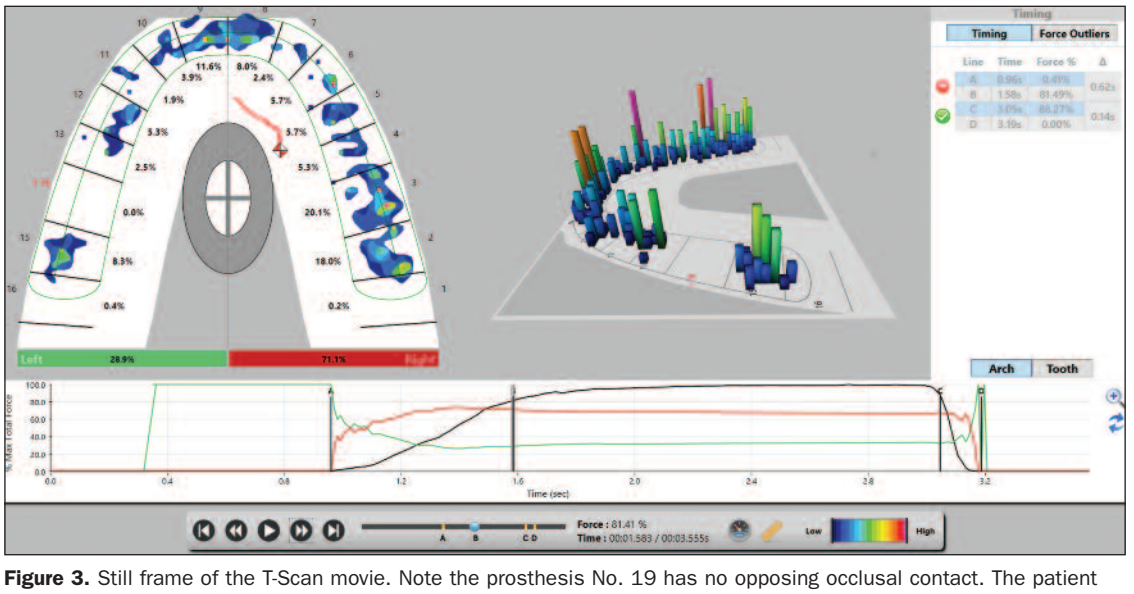

Figure 3. Still frame of the T-Scan movie. Note the prosthesis No. 19 has no opposing occlusal contact. The patient has generated more than 80% of total occlusal force with more than 70% of the total on the right side.

Figure 4. Clinical view of the prosthesis for tooth No. 19. Evidence of destruction due to occlusal stress is noted by the abractions and gingival recession.

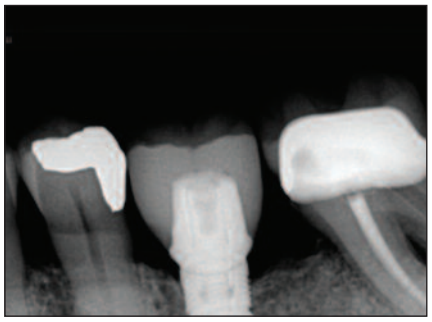

Figure 5. Radiograph of the Legacy 3 implant with straight titanium abutment and prosthesis for tooth No. 19.

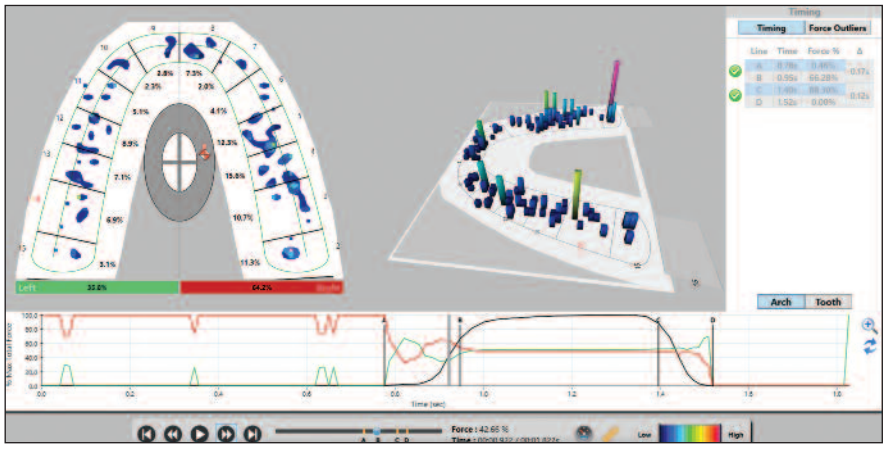

Figure 6. Still frame of the T-Scan movie. Note that at just 42% of total force application, the prosthesis is subjected to both early and high force.

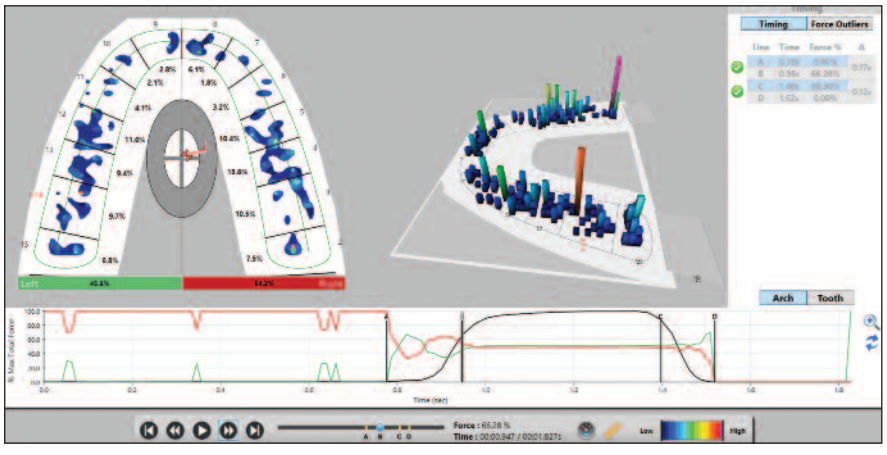

Figure 7. Advancing the movie approximately 0.02 seconds reveals the implant is still being subjected to the high early force.

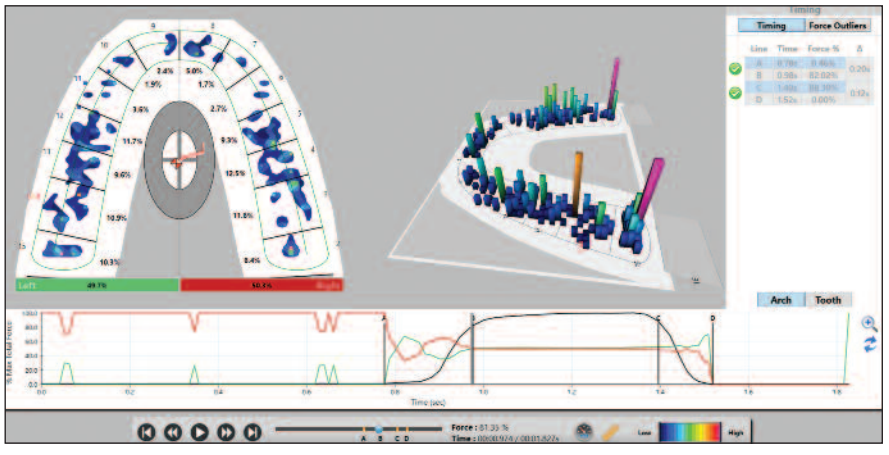

Figure 8. Playing the movie forward another 0.03 seconds shows the adjacent teeth have finally begun to absorb occlusal force to a similar degree as the prosthesis.

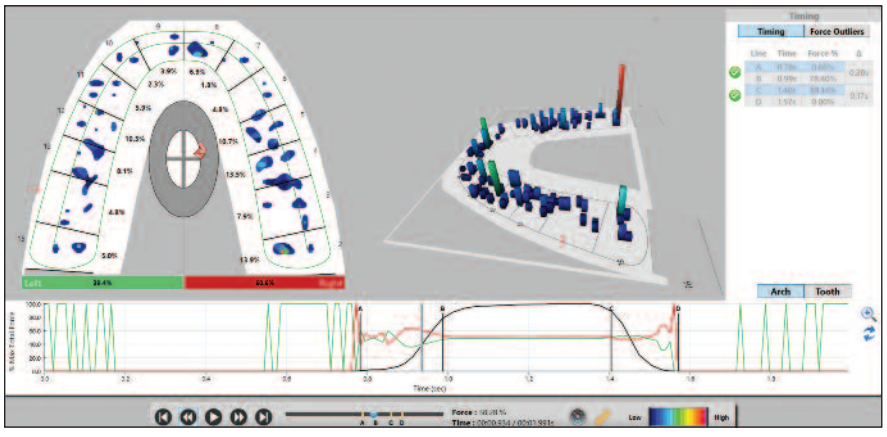

Figure 9. Following occlusal adjustments to the prosthesis, a new movie is recorded. Note the natural teeth anterior and posterior to the prosthesis are subjected to occlusal force earlier and greater than the prosthesis.

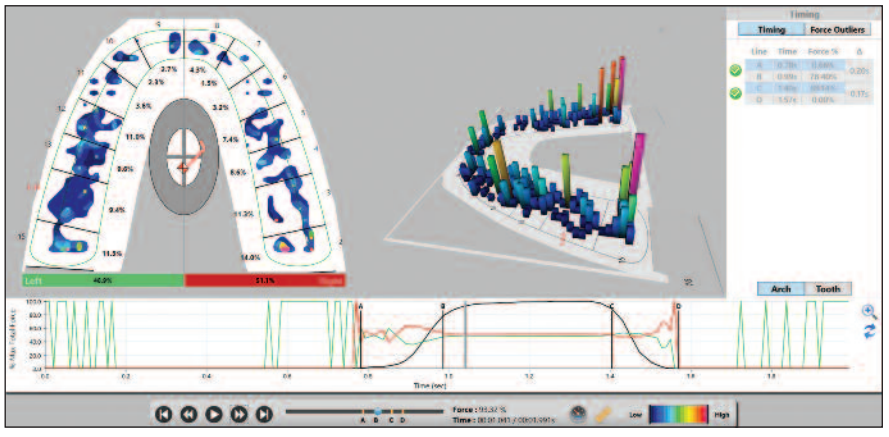

Figure 10. Advancing the movie 0.10 seconds shows the prosthesis is functional but with lower force application than the adjacent teeth (cradling).

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occlusal loading. In a clinical report by Leung et al,[13] 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[13] 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[14] 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.[14]

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 Hämmerle et al[15] 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

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periodontal ligament fibers, implants demonstrate minimal depressability in the alveolar bone when compared to a healthy tooth that experiences far more vertical depression. Parfitt[16] found that nonmobile posterior teeth depress approximately 28 µm vertically, and can move 56 to 75 µm laterally. In contrast, Sekine et al[17] 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[18] and Kim et al[19] to both suggest implants and teeth be kept independent of one another, with the implants placed into hypo-occlusion. Additionally, Hämmerle et al[15] 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[20,21] and Kirveskari[22] 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.[20-22] 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.[21,22]

Achieving a quantifiable time delay requires employing occlusal force and timing measurement technology to the occlusal contact pattern (T-Scan version 8 [Tekscan]). The T-Scan sensor (Figure 1) is nominally 90 µm thick and contains approximately 1,750 sensels of 0.05 mm² in size, which are surrounded by conductive ink that together can discern 256 differing levels of applied occlusal force.[23-28] 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 prostheses is complicated when there is a mixed implant-natural tooth occlusal scheme.

CASE REPORTS

Case 1

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[18] and Kim et al.[19] 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 an abutment and restoration were 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 ForceView, 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

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.

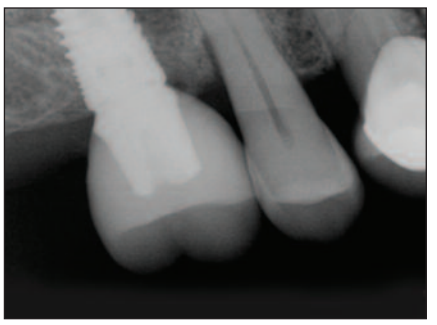

Figure 12. Radiograph of 5.2-mm diameter, 10-mm Legacy 3 implant and prosthesis for tooth No. 3.

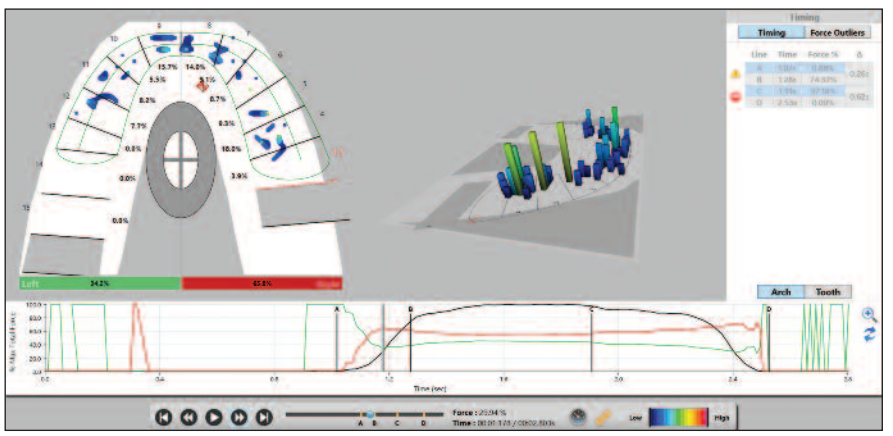

Figure 13. Still frame of the T-Scan movie. Note the teeth anterior to the implant prosthesis begin to absorb the occlusal force before the implant prosthesis.

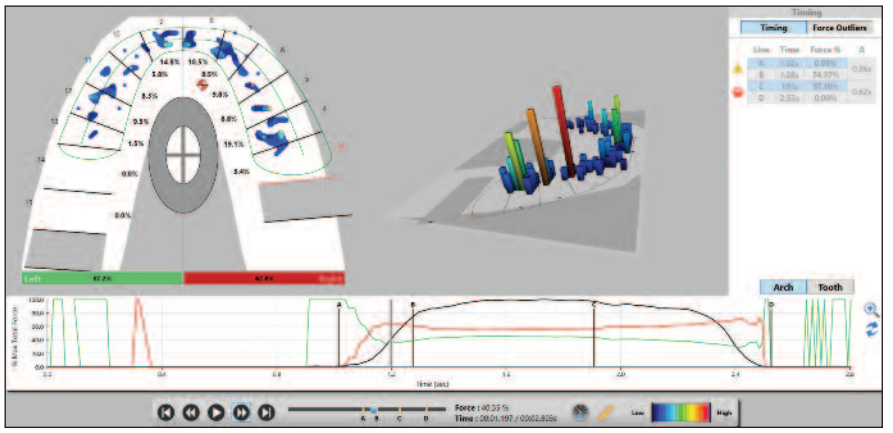

Figure 14. Advancing the movie 0.02 seconds shows an increase in force but in a "stepped" fashion with the implant still being subjected to low force.

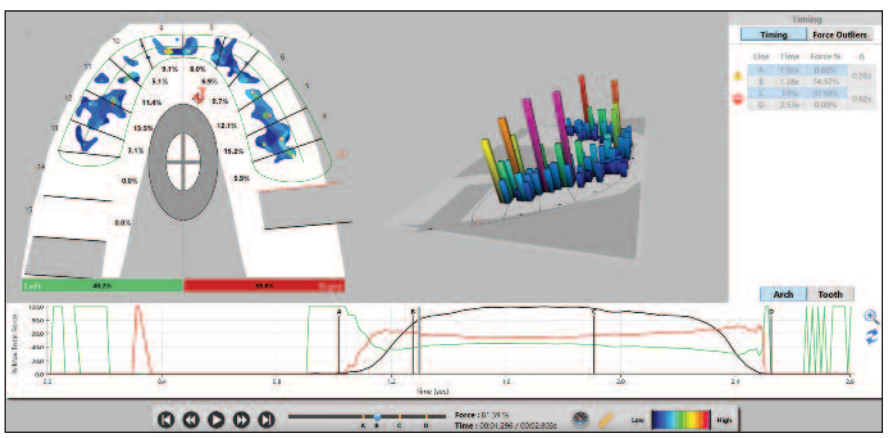

Figure 15. Advancing the movie 0.10 seconds further shows that the force continues to be greater on the natural teeth but the implant is indeed functional. The stepped appearance of force application is evident.

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 the high force is applied earlier to the implant than to the adjacent teeth. When played forward approximately 0.02 seconds, the movie shows the implant prosthesis is still subject to most of the force (Figure 7). Finally, when the movie is advanced forward another 0.03 seconds, the adjacent teeth absorb more of the applied occlusal force (Figure 8).

This patient's unperceived applied early high force will subject the implant prosthesis to repeated high stress, likely resulting in potential complications (abutment loosening/fracture, screw loosening/fracture and/or peri-implantitis including bone loss). However, with objective occlusal measurement, the force can be controlled with occlusal adjustments performed on the implant crown. Following adjustments, a new movie demonstrated the anterior and posterior teeth adjacent to the implant received the initial force loading (Figure 9). When the movie was advanced 0.10 seconds more to the terminal occlusal load (Figure 10), the teeth anterior and posterior to the implant demonstrate higher force. This higher force on the adjacent teeth to the implant prosthesis, with the later implant loading, is termed by this author as "cradling."

Case 3

The third case represents a variation of where the implant prosthesis is in a terminal position within the arch, as the patient was missing both maxillary right first and second molars, and the right mandibular second molar. The tooth No. 3 implant prosthesis (Figures 11 and 12) sits in the terminal position within the arch, making "cradling" impossible. In this scenario, the author recommends a "stepped" appearance of occlusal force.

Use of traditional nondigital occlusal indicators may be unreliable, and cannot be quantitatively analyzed.

Figure 13 illustrates that the initial forces were applied to the natural teeth anterior to the implant prosthesis. Note that the maxillary canine and both premolars demonstrate force, where as of yet, tooth No. 3 has no force applied. Just 0.02 seconds later (Figure 14), the applied force in this area has increased but in a stepped fashion, with the implant demonstrating the lowest regional force. Advancing the movie 0.10 seconds further, the force continues to be greater on the natural teeth, but the implant is indeed functional (Figure 15).

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,[29] methods to decrease stress on an implant prosthesis are appropriate and warranted, and the restorative dentist is most capable to address this condition. Chapman[30] 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. 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 preservational occlusal scheme, rather than a subjectively installed, potentially destructive one.✦

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