Tooth intrusion in implant-assisted prostheses

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Statement of problem. Numerous reports and surveys have been published on natural tooth abutment intrusion with implant-connected fixed partial dentures. The consensus of these publications was that the cause of intrusion was multifactorial, with causative factors such as disuse atrophy, debris impaction, impaired rebound memory, and mechanical binding. It was also believed that the process was irreversible.
Purpose. In this article, the limitations with these theories are discussed, and two patient reports of tooth intrusion reversal are reviewed. A review of the current literature is discussed, as well as the current theory of tooth movement in response to dynamic mechanical stimulus, a brief discussion of current experimental procedures and results, and the current recommendations for reversal of intrusion. (J Prosthet Dent 1997;77:39-45.)

CLINICAL IMPLICATIONS

The intrusion of natural teeth associated with an implant-connected prosthesis is reversible. If intrusion occurs, the reversal of the intrusion process should be started immediately. Unless the clinician has a predictable method of duplicating the energy dissipation of the periodontal ligament, attaching natural teeth to implants should be avoided. Repeated biomechanical failures of implant systems could indicate an energy dissipation imbalance in the restoration.

A decade ago, P. I. Brånemark, MD, gave the profession a protocol for restoring the dentition of edentulous patients. On the basis of 20 years of research, Dr. Brånemark recommended isolation of the implants from the natural abutments for partially edentulous situations, the use of resilient restorative materials for the occlusal surfaces of the restorations, and a retrievable design to the prosthesis. The recommendations were a compensation for the potential difference in the way natural teeth and implants would react to static and dynamic loading.

Since then, clinicians began to modify Brånemark's original recommendations. Porcelain fused to metal replaced acrylic resin on restorations because of its increased strength and the long-term esthetics provided by the porcelain.[1] Screw access holes were often eliminated because of the improvements that were desired in occlusion, esthetics, and patient comfort.[2] Implants became part of restorative treatment plans that not only included implants but other treatment modalities, such as porcelain-fused-to-metal restorations, porcelain veneers, inlays, and onlays. Ultimately, even natural teeth and implants were joined in implant-assisted prostheses as part of comprehensive occlusal restorations.[3]

These changes from the original Brånemark protocols have brought some interesting complications. One of the most surprising problems was the occurrence of tooth intrusion in implant-assisted prostheses. The purpose of this article is to explore the subject of tooth intrusion in implant-assisted prostheses. This article examines the current theories for the occurrence of tooth intrusion, two pertinent patient studies, the applicable literature from several disciplines, a hypothesis to explain the intrusion phenomenon, current research to quantify the effects of energy dissipation in dental implant structures, and current recommendations for the treatment of intrusion.

EXISTING THEORIES

In an international survey of natural tooth abutment intrusion with implant-connected fixed partial dentures (FPDs), Rieder and Parel[4] reported that the respondents felt the cause of intrusion was multifactorial and the result of causative factors such as disuse atrophy, debris impaction, impaired rebound memory, and mechanical

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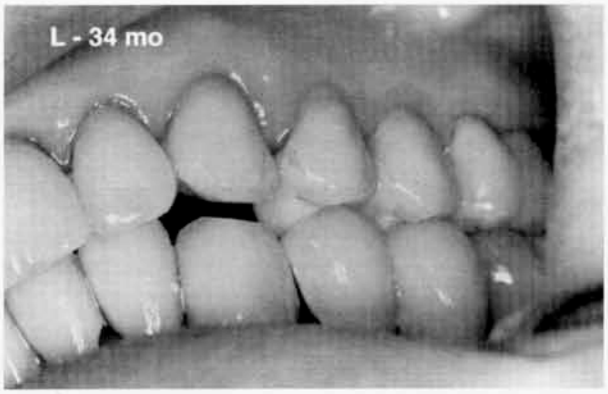

Fig. 1. Patient 1; mandibular left cuspid shows intrusion of 2 mm, evident after severing of cuspid PFM from four-unit implant-assisted prosthesis and reseating of it on mandibular left cuspid gold-milled coping as single restoration (34 months after delivery of prosthesis).

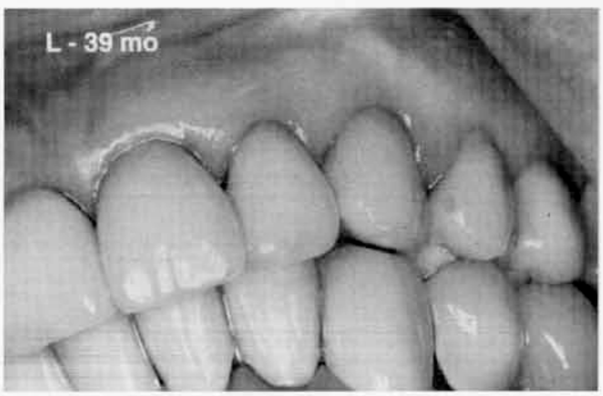

Fig. 2. Patient 1; mandibular left cuspid has extruded 1.75 mm to reverse intrusion process. Maxillary left cuspid has remained stable because of use of maxillary protective occlusal splint.

binding. The survey respondents also felt that the process of intrusion was irreversible.

Many theories have been proposed to try to explain the intrusion phenomena, but none have been fully satisfactory. For example, disuse atrophy was an early popular hypothesis for the explanation of tooth intrusion associated with implant-assisted prosthesis. However, in short-term disuse atrophy there is a marked osteoblastic activity on the periodontal membrane side of the alveolar bone and some cementoblastic activity. In long-term disuse atrophy there is practically no osteoblastic or cementoblastic activity. The supporting bone of teeth in hypofunction has fewer thinner trabeculae than the supporting bone of teeth with normal function.[5] Monkey studies have shown the width of the periodontal space to decrease significantly while the periodontal fibers underwent disuse atrophy.[6] In contrast to these findings, one of the major characteristics of tooth intrusion is osteoclastic activity before and during tooth intrusion, and at stability, a normal-appearing periodontal ligament. Therefore, the hypothesis of disuse atrophy seems inappropriate.

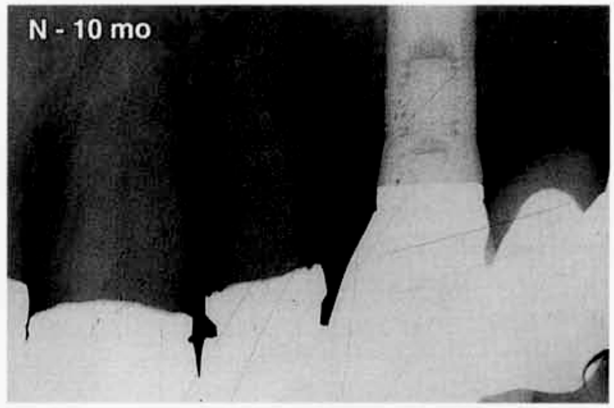

Fig. 3. Patient 2; maxillary right lateral incisor intruded 1.5 mm, and maxillary right central incisor beginning intrusion process 10 months after delivery of 10-unit prosthesis.

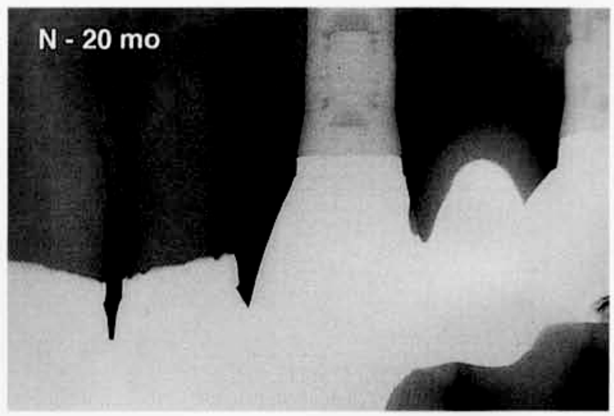

Fig. 4. Patient 2; 6 weeks later, maxillary right central and lateral incisors had extruded to their original position. Radiograph was taken at 7 weeks.

Debris impaction was a popular theory as debris was found inside some crown receptacles and contacted the occlusal surface of the intruded tooth. The theory proposes that the pressure from the impacting food forced the tooth into the bone. Restorative dental experience has demonstrated that even with poor crown margins, food impaction does not cause routine tooth intrusion. The question then is why tooth intrusion caused by food impaction would occur only in an implant-assisted prosthesis. Perhaps the solution is that when the tooth intrudes, the food debris fills the void. Debris impaction has demonstrated itself to be a "void filler" in other instances in the mouth.

For each additional theory to be evaluated, one must ask whether this problem has occurred in an all-tooth–supported situation and whether it has occurred in the extreme as illustrated in natural tooth intrusion associ-

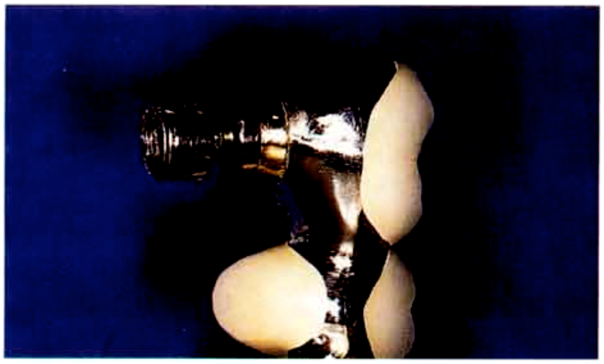

Fig. 5. Fractured distal anchorage component of patient 1, 4 years after implant-assisted prosthesis was changed to implant-supported prosthesis.

ated with implants. It is the extreme intrusion seen in a few patients studied that has been so alarming.

One of the main concerns with combining natural teeth and implants has been the lack of a periodontal ligament for the implant. From the biomechanical standpoint, natural tooth mobility itself is not as important as the stress-distributing effect of the periodontium provided by its resilient property.[7] It has been stated that an osseointegrated solid implant located in an otherwise natural dentition may disturb the unique system of resilient self-protecting, periodontally anchored teeth because it is a stiff post.[8] Also, short- and long-term loads on implants compared with loads on teeth become more important than their mobility characteristics.[9]

An article documented two patients who had experienced intrusion of natural teeth under their implant-assisted prostheses.[10] In this article, the reversal of this process was documented and a hypothesis for the occurrence was presented.

PATIENT STUDIES OF TOOTH INTRUSION AND REVERSAL

Two patient histories that illustrate tooth intrusion in implant-assisted prostheses were reviewed in detail in a previous article.[10] In each example of tooth intrusion, a change was made in the biomechanics of the implant system and subsequent reversal or extrusion of the natural tooth occurred (Figs. 1 through 4). In follow-up studies of patient 1, a 3-year recall examination radiographically and clinically demonstrated that the reversal process was stable. Patient 1's intrusion reversal treatment plan included separating the natural teeth from the implants. However, in the fourth year the patient returned to the office with a complaint of a loose FPD. She had no changes in her medical history and was faithfully wearing her protective occlusal splint when sleeping. The prosthesis was removed, and it was noted that the distal anchorage component had fractured (Fig. 5).

For patient 2, a 3-year evaluation disclosed a history of deteriorating health, increasing family stress, and a failure to wear the protective occlusal splint. Clinical and radiographic evidence showed tooth reintrusion of the maxillary right lateral incisor. (Figs. 6 and 7). Immediate protocols were instituted to start the reversal process. The superstructure was removed, the implant custom-milled transmucosal element adjacent to the intruded tooth was replaced with a healing cap. The superstructure was reseated with a petroleum jelly lubricant and the patient was instructed to wear the protective occlusal splint when sleeping.

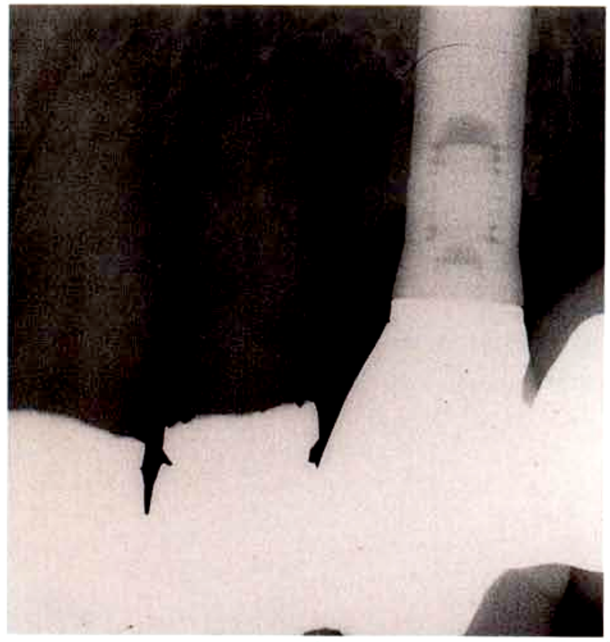

Fig. 6. Patient 2 after 3 years of stability, maxillary right lateral incisor reintruded.

Fig. 7. Soft liner (G-C Fit Checker, GC America, Inc., Chicago, Ill.) shows that maxillary right lateral coping was still in contact with internal walls of superstructure, even at maximum intrusion.

Within several days, the intruded tooth started to extrude. By 60 days the tooth was close to its preintrusion

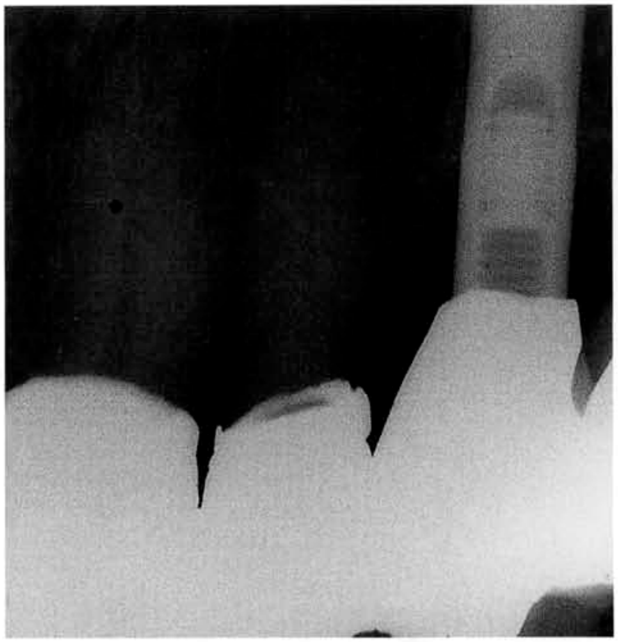

Fig. 8. Patient 2; maxillary right lateral incisor reveals successful second reversal of intrusion.

position and stable. The implant transmucosal element was remilled to provide a more substantial layer of cementing medium and was reinserted. The superstructure was subsequently recemented on the copings with a temporary cement (Temp Bond, Kerr Manufacturing Co., Romulus, Mich.). No cement was placed in the receptacle for the right lateral incisor. The absence of cement in the superstructure receptacle for the maxillary right lateral incisor allowed for final reseating movement of the tooth into the superstructure. The patient was counseled regarding the role of parafunctional habit patterns in intrusion, and use of the protective occlusal splint during sleeping hours was stressed (Fig. 8).

SURVEY OF THE CURRENT LITERATURE

One of the first clinical reports of apparent intrusion of natural teeth under an implant-supported prosthesis was published in 1992.[11] The authors concluded that the cause of intrusion was unknown. Recommendations were made that once osseointegration was confirmed, the natural teeth should be extracted to avoid the intrusion problem.[11]

English[12] published two articles on tooth intrusion in 1993 and listed seven potential etiologies for intrusion: disuse atrophy, mechanical racheting/binding of the nonrigid connector, microjamming of the nonrigid connector from food impaction, energy absorption phenomena, periodontal ligament rebound with restored posterior occlusion, fixed partial metal flexion, and mandibular flexion and torsion. English[13] stated that there is no clear consensus at this time as to the etiology of root intrusion and that root intrusion that is not an isolated occurrence merits serious investigation as to its etiology to enable clinicians to treat combination tooth-implant cases with problem-free and predictable methods.

Murphy[14] reminded us that Wolff's law of transformation is as valid for the mandible as it is for all bones of the skeleton. Remodeling the mandible after functional loading of implants supports this view. Odman et al.[15] reported that implants function well as orthodontic anchorage units in adult patients because the implants resisted displacement forces in all planes. There was no movement of the implant through the bone as is evidenced in natural-tooth orthodontic movement. Upon functional loading, teeth and implants react differently. Responding to Wolff's law, implants build up denser bone, whereas teeth tend to respond by moving away from the applied pressure.

The orthodontic literature provides significant insight into the process of natural tooth movement. In their finite element analysis of stress in the periodontal ligament, Wilson et al.[16] concluded that the stress distribution within the periodontal ligament is complex. Their results indicated that there may be a viscoelastic nature (an energy dissipating feature) to the periodontal ligament. Melsen et al.[17] reported on the intentional intrusion of incisors of adult patients with marginal bone loss and found that root intrusion was maximized when the gingival status was healthy, no interference with perioral function was present, and forces were low (5 to 15 gm per tooth) with the line of action of the force passing through the center of resistance. This precise set of criteria to increase orthodontic intrusion efforts is what is created unintentionally in many tooth/implant restorations.

Clark et al.[18] focused on the cellular level in their analysis of the effect of tooth intrusion on the microvascular bed and fenestrae in the apical periodontal ligament of the rat molar. Their study demonstrated that tooth intrusion produced a significance increase in vascular volume, the number of arterial capillaries, and the endothelial surface area. After tooth intrusion, a significant reduction occurred in the number of fenestrae per square micrometer of endothelium in postcapillary-sized venules and venous capillaries.[18] In a study on the effect of oxygen on osteoblastic function, Tuncay et al.[19] found that compressive forces result in low partial pressures of oxygen in the periodontal ligament that subsequently stimulate bone resorption. High oxygen levels that result from a reduced amount of compression result in bone formation. When the oxygen levels are in equilibrium, there is no tooth movement. When there is a lack of equilibrium, the tooth will extrude or intrude.[19]

The influence of Interleukin 1 beta and prostaglandin E on periodontal cells as they respond to mechanical stress has been the subject of in vivo and in vitro studies. The results have revealed that periodontal ligament cells respond to mechanical stress by increased production of PGE, and that IL-1B enhances this response. IL-1B is

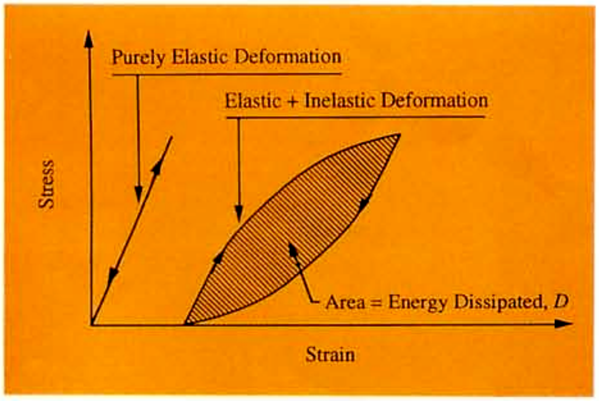

Fig. 9. Straight line represents purely elastic deformation seen in implant structures. Shaded area in hysteresis curve shows energy dissipated in elastic-inelastic deformation combination as seen in natural tooth–periodontal ligament complex.

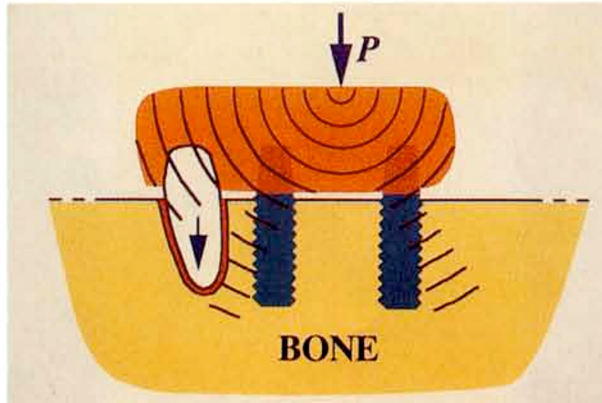

Fig. 10. Force (*P*) impacts on connecting prostheses. Because of the lack of energy dissipation, natural tooth receives a relatively high amount of mechanical stimulus.

released by the WBCs as an immune response to mechanical stimulation. Human periodontal fibroblasts have responded in vitro to the application of mechanical stress and the administration of cytokines by elevating the synthesis of PGE, a potent stimulator of bone resorption.[20] Therefore, mechanical stress of the human periodontal ligament starts a chain of events on a cellular level that results in bone resorption.

Davidovitch[21] reported that bone cells appear to be sensitive to short-duration exposures to mechanical loads whose distribution in the bone matrix deviates from their regular dispersion pattern. This clinically effective force should be somewhat biodisruptive, thus it should be capable of causing an inflammatory/reparative reaction in the periodontal ligament (PDL) and alveolar bone. Davidovitch's description of a clinically effective force corresponds to the impact forces and repeated parafunctional loading placed on the dentitions of many patients during parafunctional activities.[21]

Mechanical studies illustrate the importance of a stress-breaking component when an osseointegrated implant is to be splinted to a natural abutment.[22-25]

THEORY OF TOOTH MOVEMENT IN RESPONSE TO DYNAMIC MECHANICAL STIMULUS

In 1993, a hypothesis for the occurrence of natural tooth intrusion in implant-assisted prostheses and its reversal was published.[10] The article stressed the importance of energy dissipation in dental implant systems. Natural teeth and dental implants dissipate mechanical energy in different manners. Because of their rigidity, dental implants are energy conservative. As a result, the mechanical stress created by a dynamic impact force on an implant-borne prosthesis is transferred from one end of the implant-abutment-restorative complex to the other with little attenuation. The deformation in this example

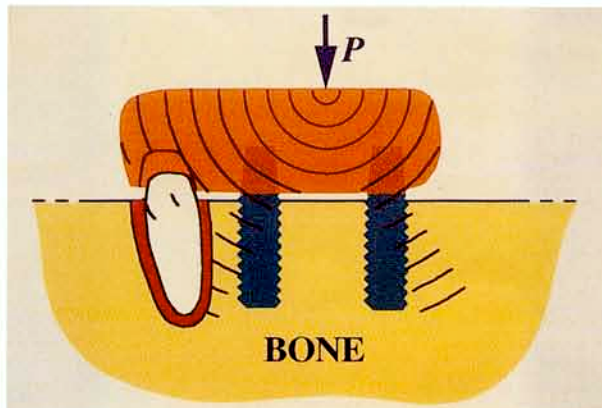

Fig. 11. Mechanical stress acts as orthodontic force to stimulate cellular response in osteoclasts and osteoblasts and results in tooth intrusion.

is predominantly elastic, where no or minimal mechanical energy is absorbed by the implant. In addition, the bone surrounding the implant is only mildly absorptive of the generated mechanical energy.

In contrast, a different pattern of energy dissipation emerges for natural teeth. The natural tooth receives the impact energy and transfers it to the end of the root in the form of a stress wave. Some energy is reflected back up the tooth structure, but most of the energy is dissipated by the highly absorptive periodontal ligament. This process dissipates a high amount of mechanical energy and is an example of combined elastic and inelastic deformation. These concepts are graphically illustrated in Figure 9, where the shaded portion represents the energy that is dissipated or absorbed by the periodontal ligament.

A natural tooth that supports an implant structure can receive an abnormally high level of mechanical stress because it is connected to an energy conservative structure

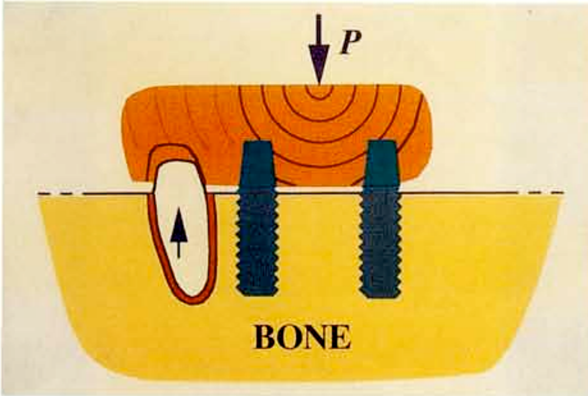

Fig. 12. Change in implant abutment complex allowed increased energy absorption by implants, which lessened mechanical stress transmitted to natural tooth. Resultant equilibrium change stimulates osteoblasts and/or cellular components to start extrusion process.

(Fig. 10). On the basis of the hypothesis previously reported, this abnormally high stress can act as an orthodontic force, causing the natural tooth to intrude (Fig. 11). Once the tooth has moved either out of contact with the prosthesis or to a position where the amount of mechanical stress is no longer strong enough to generate tooth movement, the process stops. The tooth will remain in the new position until there is a disruption in the equilibrium of the energy dissipation (Fig. 12). Once the equilibrium is changed, the tooth will either extrude or intrude.

PARALLEL LABORATORY RESEARCH

Diagnostic instrumentation and software have been developed for a parallel study of energy damping in dental implant materials and structures.[26] The experimental system consists of hardware and software that are interfaced to a Siemens Periotest instrument (BioResearch, Inc., Milwaukee, Wis.)[27,28] that has been modified for this investigation. This new system performs a quantitative measurement of energy-damping capacity that, in engineering terms, is commonly referred to as the loss coefficient. Accordingly, the measurements may be compared with tabulated values obtained with other testing methods that are more commonly used but not capable of measurements on implant structures.[29] In addition to being able to test in vivo specimens, the Periotest instrument gives added relevance to the measurements for dental applications, because it was designed to impact teeth under loading conditions that are consistent with mastication.

Loss coefficient data for an in vitro porcelain-fused-to-metal superstructure seated with temporary cement (TempBond, Kerr Manufacturing Co.), petroleum jelly (Vaseline, Cheeseborough Pond's, Inc., Greenwich, Conn.), and artificial saliva (saliva substitute, Roxane Laboratories, Inc., Columbus, Ohio) are summarized in Table I. The load transmitted through the structure

Table I. Loss coefficient as a function of seating medium for a porcelain fused to metal superstructure

Seating medium	Loss coefficient*	Transmitted load(N)
Temporary cement	0.095	9.7
Petroleum jelly	0.102	6.3
Artificial saliva	0.105	5.9

*Average of 50 measurements; maximum standard deviation is 0.002.

from the Periotest instrument impacts was also measured with a load cell to asses the change in mechanical stimulus as a function of damping capacity. The data indicate that the luted superstructure exhibits a significantly lower loss coefficient than the superstructures seated with either petroleum jelly or artificial saliva. This result is expected because, unlike that for the other two media, the cement prevents energy dissipation by interfacial sliding between the superstructure and abutment. The difference between the loss coefficient values for the superstructures seated with petroleum jelly and that for artificial saliva is considerably lower. Apparently the relative viscosities of these two media are sufficiently similar to result in loss coefficient values that are nearly the same. It should be noted that the superstructures seated with petroleum jelly and artificial saliva were completely seated to the abutment before the loss coefficient values were measured. Hence, these measurements should be considered lower bound values because the loss coefficient can be substantially higher when the superstructure is not completely seated. Similarly, the transmitted loads should be considered upper bounds for the two viscous media because an increase in the damping capacity results in a decrease in transmitted impact load.

In sum, the results in Table I indicate that reseating the superstructure with petroleum jelly, as performed in the aforementioned clinical study, results in a significant increase in the damping capacity of the prosthesis that, in turn, reduces the impact load transmitted by the structure. Thus, the data are consistent with the hypothesis that this procedure would result in a decrease in the mechanical stimulus to an integrated natural tooth. Further evidence from the experimental study on damping capacity is the subject of a future article.

CURRENT RECOMMENDATIONS

On the basis of current knowledge about all titanium implants, several recommendations are made.

1. Combining implants and natural teeth should be avoided, because there is no universally accepted system presently existing that is capable of replicating the damping effect of the periodontal ligament.

2. New techniques should be explored that allow a safe connection of teeth to implants.

3. The factors that are generating mechanical stress should be changed when intrusion has occurred. The treatment may include: (1) modifying the design of the

prosthesis, (2) using lubricants to dissipate energy, (3) minimizing parafunctional stresses by the use of protective occlusal splints, (4) adjusting the occlusion to minimize untoward forces, and (5) modifying adjacent implant abutments to be more absorptive of mechanical stress.

Additional research is needed to explore the important area of energy dissipation in dental implant systems. Certainly other less dramatic, but equally frustrating problems, such as screw loosening, screw fracturing, prosthesis repair and maintenance, and abutment failure due to metal fatigue may also be a result of improper energy dissipation. It has been reported that more than 50% of prosthetic problems are related to stress factors acting on the prosthesis.[30] The field of bioengineering is fast becoming a significant contributor to the long-term success of implant prostheses.

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