Diet and Implant Complications

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A hard or coarse diet may impart a substantial off-axial load to dental implant-supported prostheses and may induce a component, implant midbody fracture or late loss of integration. This may be especially true when there is a large crown to implant ratio. A patient who is able to generate an excessive bite force along with chronic cyclic loading with hard or coarse foods may have implant body or component fractures. There are no established parameters for crown to implant ratio or for detrimental bite loads. Implant longevity may be dependent on many factors, including the supporting bone quality and volume, crown to implant ratio, implant width and length, the prosthetic occlusal scheme and bite force/arc location, and the patient’s dietary load.

Key Words: dental implant, implant fracture, component fracture, bone, splinting, diet, cyclic load

INTRODUCTION

Once a dental implant-supported prosthesis is delivered for patient function, the patient’s dietary habits come into play. Some patients have food preferences that may be detrimental to the longevity of implant-supported fixed prostheses.

The chronic cyclic loading and variable magnitudes in human oral functioning may be an important factor when considering a potential mechanical problem such as metal or osseous fatigue. A diet that generates repeated, substantial off-axial loading may induce a late implant failure or fixture fracture. The forces of occlusion are generally in a range of 50 to almost 400 N.1 These forces, when applied cyclically and off-axially, may induce detrimental micromovement of an integrated implant, which could induce fibrous replacement at the implant-bone interface. This may occur when there is a mechanical advantage created by a large implant to crown ratio. This allows a microluxation of the implant fixture in the bone and the subsequent hemorrhage and fibrosis. Nevertheless, when the bone is substantial and resistant to the loads applied then this force may be retained by the implant as a strain. Subsequently, an implant fracture may occur due to metal fatigue in the implant body or a component.

A larger-diameter implant surface area accepts the same load magnitude against the supporting bone, but the load is dissipated over a large osseous surface area.3 So a larger diameter may be more appropriate in high load areas or in patients who generate large bite forces or have significant dietary offensives.

The object of this discussion is to review the patient dietary factors that may induce a late implant failure or fracture.

CASE 1: SIGNIFICANT RAW VEGETABLE DIET

This patient was a 56-year-old Asian man who consumed a diet rich in raw vegetables. He was treated with a dental implant for site #14 on September 12, 2005. The bone quantity and quality were attenuated (Figure 1). The antrum had pneumatized, leaving approximately 5 mm of residual bone height. A 5 mm × 7 mm scinted implant (Endopore, Innova, Toronto, Canada) was placed using an osteotome compressed sinus-floor elevation technique. A collagen plug was placed through the osteotomy and pressed into the sinus lining to elevate it. Osseous allograft (Puros, Zimmer Biomet, Warsaw, Ind) was then introduced through the osteotomy using a 1-ml syringe while pressed against the sinus lining with a round osteotome. An additional collagen plug was then pressed into place, the implant was press fit, and the surgical flap was closed with 4-0 polyglycolic acid (Vicryl, Ethicon, New Brunswick, NJ). The implant was pressed beyond the sinus floor, approximately 2 mm. The patient was medicated with amoxicillin with clavulanic acid 875 mg twice a day for 1 week. The implant was allowed to heal for 5 months (Figure 2). An abutment was placed and a flat no-cusp crown was constructed with approximately 100 µm occlusal relief and cemented with zinc phosphate cement (Flecks, Keystone, Gibbstown, NJ). After about 4 years of service (August 31, 2009) the implant became mobile, was removed, and the defect debrided. The osseous rim and floor were intact, so the sinus floor was elevated again with a round osteotome and grafted with collagen plug, particulate allograft (Puros), calcium sulfate, and collagen plug layers. After 6 months of healing a large-diameter implant (5.7 mm × 10 mm, Implant Direct, Ventura, Calif) was placed with only osteotomes and no drill preparation. After 6 months of healing, a new, flat, no-cusp crown was constructed and cemented. This has now been in function for 6 years without incident (Figure 3). Thus, a daily raw vegetable diet may produce extreme cyclic off-axial loads and increase the risk for failure.

CASE 2: HIGH-MAGNITUDE BITE FORCE

This patient, a 68-year-old male, had a very high magnitude jaw biting force, 1200 N. He routinely ate meats of all cuts and textures. A 3.7 mm ×11.5 mm implant fixture was placed to support a long-span provisionally cemented 4-unit fixed partial denture (#11–14) (Figure 4). The 3.7 mm diameter implant #11 failed after 4 months of function. The mandibular left cuspid

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DOI: 10.1563/aaid-joi-D-15-00127

FIGURES 1–7.

**FIGURE 1.** Preoperative radiograph of the first molar site shows a well-pneumatized sinus, limiting available bone volume.

**FIGURE 2.** A scintered (5 mm × 7 mm, Innova) implant was placed with an osteotome sinus-floor elevation technique. An amount of new bone formed, the abutment was placed, and the definitive crown was placed. There was a large implant fixture to crown ratio, and the patient followed a raw vegetable diet. The implant failed under the occlusal load 6 years later. The amount and/or quality of native and formed apical bone were inadequate to support the dietary occlusal load.

**FIGURE 3.** The (5.7 mm × 10 mm, Implant Direct) implant was replaced with an osteotome sinus-floor elevation technique and has had uneventful function for 6 years. The bone surrounding the large-diameter fixture is apparently adequate to resist the dietary occlusal forces.

**FIGURE 4.** A long span (4 unit) fixed partial denture was supported by 2 implants. The patient has a 1200 N bite-force capability, and the anterior implant failed early under the load.

**FIGURE 5.** The failed implant was removed, the site debrided, and a larger diameter implant immediately placed.

**FIGURE 6.** A definitive fixed partial denture was fabricated and cemented. It has been in function uneventfully for 2 years.

**FIGURE 7.** After 12 years of function a single implant body fractured. The patient has had a daily popcorn consumption habit for decades.
contacted the lingual aspect of the #11 implant crown during the working excursion in an anterior guided occlusal scheme. The maxillary lateral incisor was also engaged, but it moved facially, physiologically limited by the limits of the periodontal ligament. Thus, a portion of the load was borne by the implant in an off-axial or facial vector. The failed implant was removed, the site was debrided, and a larger diameter (4.7 mm × 13 mm Implant Direct, Valencia, Calif) implant was immediately placed. After 4 months of healing, a 4-unit fixed partial denture was constructed, provisionalized, and subsequently definitively cemented with resin modified glass ionomer cement (Relly X, 3M ESPE, St Paul, Minn) (Figure 5). It has been in function uneventfully for 2 years.

CASE 3 MB: DECADES OF DAILY POPCORN CONSUMPTION

This patient was a 61-year-old female. A missing maxillary left second premolar was restored with a 3.25 mm × 13 mm implant (I-I, Palm Beach Gardens, Fla) placed on January 31, 2002, with an apically positioned full/split flap that was nonsubmerged. The crown was placed on June 6, 2002. There was uneventful function until December 12, 2014 when a midbody implant fracture occurred (Figures 6 and 7). There was slight bone loss over the years, thus increasing the crown to implant ratio. The patient had consumed a daily diet of 1 or 2 bags of popcorn for many years. The chronic daily consumption of popcorn may have induced a daily off-axial load, inducing an unusual midbody fracture. Popcorn is notorious for containing unpoppered kernels that the consumer may not notice. These hard kernels are crushed by the patient’s dentition, causing a sudden large-magnitude biting load. This force can be off-axial and have consequences for the supporting bone and the implant fixture. Many fractures occur in the abutment screw or as an in-bone overload, causing a failure of osseointegration. This patient, however, had long-standing osseointegration and slight cervical bone loss. Thus, the off-axial dietary loads may have been directed to the implant midbody area and caused the fracture. The patient opted to not retrieve the fractured portion.

DISCUSSION

Crown to implant ratio and bone support

After implant placement, bone remodeling through the coordinated activity of osteoblasts and osteoclasts allows the osseointegration of dental implants. Remodeling may increase the supportive qualities of a loaded implant fixture. The resistance to occlusal forces ultimately depends on the resistance of the osseous collagen polymer. The patient’s bite force capability is the origination of the occlusal force. However, there is great variability in the magnitude of occlusal forces generated by patients. The osseous-collagen polymer mineral complex must resist these forces as they are transmitted through the implant prosthetic complex. Of most concern are the lateral or off-axial forces that may cause collagenous interpolymeric molecular breakage (Figure 8). A greenstick fracture may occur, causing loss of integration. Survival of implants with high implant crown ratios may depend on the ratio leverage created, bone density, and jaw force generated at that particular arch site (Figure 9). When the supporting bone is resistant to off-axial loads, this then directs the load to the implant fixture.

A disadvantageous lever is created when there is a high crown to implant ratio. It is likely that the critical crown to implant ratio for implants is much larger than 1:1, as in natural teeth. Dental implants may not be subject to the same biological rules as natural teeth due to material and anatomical differences. There are, at this time, no highly credible evidence-based reports for an appropriate crown to implant ratio.

The conditions of the cases presented herein differ somewhat from each other. The radiographic crown to implant ratio in case 1 was 2:1 (14 mm to 7 mm). The in-bone implant portion was 7 mm (5 mm × 7 mm Innova Endopore) and the coronal portion was 14 mm as measured on a periapical radiograph. The surface of this particular implant is theoretically increased due to the sintering manufacturing process, which may create a much larger area for bone to engage. The sintered surface dramatically increases the potential for bone to implant contact (BIC). However, the actual amount of bone that does indeed make contact with the implant surface is unknown and probably varies among sites and patients. Obviously, the increased surface could not compensate for the osseous quality and the dietary and occlusal forces of the patient. Additionally, the osteotome sinus-floor elevation and osseous graft may not have induced a substantial amount of dense bone for adequate support, thus potentially lessening the actual BIC. Additionally, the 5-month healing time for osseointegration may have been inadequate for this particular patient’s healing capacity. Additional time may have been required for osseous calcification and density. Alternatively, the implant was in function for many years, providing adequate time for calcification. The crown to implant ratio and diet may have been too imposing to resist the occlusal force, regardless of the scintered implant surface and BIC.

One study found the average ratio in failed implant crowns was 1:1.4. The range of crown to fixture ratios was 0.5:1 to 3:1. A range indicates that different sites support implants with more or less support. While many ratios of failed implants were reported to be below this mean, there were many with larger ratios, and several of those implants were reported successful. The time lag between placement and manufacture was not indicated, nor were dietary considerations. Thus dietary loads may be a factor, and the varying bone qualities and volumes may affect long-term outcomes (Figure 8). In these cases, the osseous site and oral mechanical dietary conditions were probably different. The BIC becomes important when there is increased loading. The BIC may have been higher and the osseous quality may have been denser in the successful sites and thus able to withstand cyclic dietary occlusal forces. Alternatively, the individual patient’s biting-force capability may or may not have been overwhelming to the implant integration support.

A larger-diameter implant fixture exerts less lateral force per square millimeter against the supporting bone. The denser and thicker the bone is in the site, the more osseous resistance to these exerted loads. In case 1, the implant size (diameter and length) may have been inappropriate for this patient’s dietary
occlusal force and quality and quantity of available bone. There are no universally accepted parameters or mathematical formula to direct the clinician to the most appropriate size implant fixture for a given edentulous site. The clinician must depend on their clinical judgment. Currently, the bone quality and volume needed to resist a particular patient’s jaw force occlusal load is unknown.

Occlusal schemes that protect implants from excessive off-axial forces should be considered. The minimization of off-axial force may function to avoid overwhelming the supporting bone or fatiguing the metallic fixture or components. The chronic off-axial cyclic loads delivered to posterior implants by a balanced occlusion in fixed prosthetics may induce metal fatigue, fracture of the implant fixture or abutment screw, or induce screw loosening. The rate of implant fracture may be less than 5% over 10 years. However, some implant designs may be prone to fracture if there is an occlusal overload. Implants that support single crowns or fixed partial dentures may be more susceptible to fracture compared with full arch restorations. Splinting or combining implants as well as cross arch stabilization for fixed restorations may prevent long-term overload complications.

The implant’s position in the arch may affect the magnitude of force to which it is subjected. Anterior locations are under about one-third the load of posterior positions.

Diet and Fracture

Figures 8–11. Figure 8. The osseous collagen polymer allows for minor molecular interpolymeric bond breakage thereby preserving the main chain and allowing bone to “stretch.” The interpolymeric bonds can break leaving the main polymeric chain intact. This gives bone toughness and an ability to not completely fracture under load. This is characteristic of a greenstick fracture. Figure 9. A lateral force causes a rotation of the fixture around a point near the platform. When there is adequate osseous support, no appreciable movement occurs. The bone resists the compressive, shearing, and tensile forces, and the fixture does not move. Figure 10. Thin facial cortex or poorly calcified grafted bone allows the implant fixture to move under a lateral force, thus causing a luxation and subsequent interstitial hemorrhage and epithelial down-growth. Figure 11. When the osseous cortex is thick there is better resistance to loading. When there is a thin cortex there may be a risk for a late failure under load.
If an implant fixture fracture does occur, the in-bone fractured remnant may be removed to prevent bacterial colonization or obstruction of an additional or replacement implant.\textsuperscript{14} Another shorter implant may be placed in the site to entomb the fractured remnant deep in the bone.\textsuperscript{15} This technique was used for a fractured implant where the remnant apex was located on the roof of the mandibular canal.

The BIC varies from 20\% to 80\% in osseointegrated implants.\textsuperscript{16} Common sense indicates, the more bone contact the more resistance to compression and tension to limit micromovement under occlusal load. Osseous cortex provides the most bone contact because it is very dense and without trabeculations. The cortical osseous crest bears the most stress on loading (Figure 10). Thus, compression, tension, and shearing forces occur at the 4 aspects of the implant cervical under load. It is concluded that the denser the bone, the more resistance it is to these forces, which limits micromovement. If more than 50–150 \( \mu \)m of micromovement occurs there may be a microhemorrhage and fibrous tissue healing and loss of osseointegration.\textsuperscript{17} Bone density is a result of collagenous density and calcification, which makes bone hard and tough. The erratic and disorganized positioning of collagen fibers and the interpolymeric bonds give bone toughness and resistance to fracture. The main polymer chain is very strong and rigid, but the interpolymeric molecular bonds are relatively weak and break when stressed (Figure 8).\textsuperscript{4–6} Thus, a greenstick fracture occurs because there is a fracturing of the interpolymeric molecular bonds while the main polymer remains intact.\textsuperscript{4–6} A dent or impression is made in the bone, but there is no complete fracture. When bone is under load and a microtype greenstick fracture may occur, there may or may not be a loss of osseointegration. This may depend on several factors, such as the magnitude of the polymeric displacement or molecular damage. When osseous fracture healing occurs, it depends on compressive, shear, or tensile microdamage; the blood supply of that area; the ability of the implant to remain immobile to allow for reosseointegration; the patient’s healing capacity; and subsequent overloads that may induce an additional microfracture. It is not known at what point appositional osseous repair or fibrous ingrowth occurs. If the coronal aspect of the implant micromoves and there is a break in the crest epithelial attachment, there would likely be an epithelial reparative invasion that would appear clinically as a mobile implant. A radiolucent area between the implant and bone may appear. If the implant loses a certain amount of immobility and continues to luxate, the epithelium could advance to completely surround the implant and result in exfoliation.

**Dietary considerations**

Some patients consume a regular diet that consists of coarse foods, such as raw vegetables and nuts, which may require increased jaw forces to adequately morselize these foods. The chewing of these foods may place higher magnitudes of force on the bone than in those patients who eat softer foods. The frequency of the loads may be an issue in osseous overload as well. One episode of overload may not initiate an implant failure, but cyclic chronic overload over a period of years may induce osseous or metal fatigue. Where bone is truly supportive, an off-axial load or a high crown to implant ratio can also induce microstrain in the bone in the appositional range.\textsuperscript{18,19} The apposition of bone would result in increased strength.

Popcorn contains the occasional unpopped kernel that the consumer may not notice. These are commonly bitten down with a sudden crunch. When the kernel is crushed at the implant crown site, there may be a definitive off-axial loading vector to the facial and lingual aspect, which may occur in alternating sequence. After many years of function, as with the patient in case 3, metal fatigue may be induced with subsequent implant fixture fracture. Chronic consumption of popcorn and other hard foods that crunch may create long-term loading issues that result in metal fatigue. This may be especially important where the implant fixture has lost cervical bone, thereby increasing crown to implant ratio.

Generally, wide-diameter implants can be used to reduce the per square millimeter of osseous load. Nevertheless, many sites cannot accept large-diameter implants or the supporting bone may have thin cortices that do not provide adequate load resistance. The sudden crunching of hard food orbs may indeed produce detrimental cyclic, off-axial loads in these chronic eaters of hard foods.

Some patients chronically chew ice (known as “pagophagia”), which may be a particularly harmful habit.\textsuperscript{20} The density and temperature of ice may induce cracks and fractures in natural teeth and prosthetic porcelain.

**Bite force**

The range of bite force has been found to be 50–2000 N.\textsuperscript{21–23} A portion of the patient population may be at the higher end of this range and thus impart a large magnitude of loading. While axial loads are generally well tolerated by dental implants, they are also detrimental and may result in micromovement and microhemorrhage at the implant to bone interface, especially when chronic and cyclic. Subsequent fibrosis ensues and the implant fails. A cortical thickness at a minimum of 1.8 mm may be necessary to adequately resist off-axial loads for long-term functional and esthetic outcome (Figure 11).\textsuperscript{24} This dimension may become important generally, or especially with patients who produce a high-magnitude biting force. The load tolerance of cortical bone in any particular patient is not measurable at this time. Nevertheless, it is the clinician’s responsibility to ensure a successfully functioning prosthesis. Measuring the residual facial cortex thickness by cone-beam computed tomography and bite-force capability may be part of the preoperative patient assessment.\textsuperscript{25,26}

Patients may be able to control biting forces in varying food textures and densities. During mastication of food, various jaw muscles are activated with variable forcefulness as different textures and densities of food are encountered. This means that variable magnitudes of loads are delivered to an implant-supported crown or fixed partial denture.\textsuperscript{24} An inadequate thickness or quality of facial cortex may cause a greenstick fracture under the load and result in an osseointegration failure.\textsuperscript{24} Jaw bite force may not be decreased when there is masseter and temporalis pain, such as during temporomandibular dysfunction.\textsuperscript{27} Jaw muscle pain may have only a slight effect on the magnitude of masticatory function.

Interestingly, patients may generate higher biting force on the ipsilateral dominant-hand side of the jaws.\textsuperscript{28} The clinician...
Fracture and failure of an implant fixture or component or loss of integration may be multifactorial. Nevertheless the patient’s diet may be a contributory factor. Significant dietary cyclical off-axial loads may induce an implant midbody fracture or late loss of integration. Inadequate bone quality and volume may allow an implant osseous failure. When there is adequate supporting bone quality and volume and a significant crown to implant ratio, an implant component or fixture fracture may be induced. This may occur in patients that generate a high bite-force magnitude or have chronic excessive cyclic loading with hard or coarse foods. There are no established parameters for crown to implant ratio or detrimental bite loads. The bone quality and volume needed to resist a particular patient’s jaw force occlusal or dietary load is unknown. Credible studies need to be done to elucidate this issue.

**ACKNOWLEDGMENT**

The author acknowledges the kind and gentle redactions of Danielle Green, DMD.

**REFERENCES**