Evaluation of the ITI Morse Taper Implant/ Abutment Design with an Internal Modification

Thomas A. Ding, DDS, MS[1]/Ronald D. Woody, DDS[2]/Frank L. Higginbottom, DDS[3]/Barbara H. Miller, DDS, MS[4]

Purpose: *The purpose of this study was to compare internal Morse taper connections in 2 separate modes: repeated torque/reverse-torque values and compressive bending at a 30-degree off-axis angle.* ***Materials and Methods:*** *Three sample groups (n = 12 in each group)—a solid-screw implant paired with a 5.5-mm solid abutment (SSI), a synOcta implant with a 5.5-mm solid abutment (SOI), and a synOcta implant with a synOcta 5.5-mm solid abutment (SOSA)—were torqued to 35 Ncm, and the reverse torque to remove the abutment was recorded. This was repeated for 3 trials. Additionally, the sample groups were loaded 30 degrees off-axis, and the ultimate compressive values were recorded.* ***Results:*** *There was a significant difference in the initial reverse-torque values. The SOSA setup showed significantly lower torque than the SOI and SSI setups ($P < .05$). In addition, the compressive bending test showed that the SOSA setup was significantly different ($P < .05$) from the SSI and SOI setups. Radiographic survey of the test groups following compressive bending revealed no implant fractures, but bending of the implant-abutment complex occurred.* ***Discussion:*** *The alteration within the Morse taper did not reduce the strength of the implant-abutment connection, ie, the reduction in surface area did not significantly reduce the torque properties or tensile properties. The new 2-piece synOcta 5.5-mm solid abutment was shown to have a stronger implant-abutment connection when torqued down a second time.* ***Conclusions:*** *In this in vitro study, alteration of the Morse taper with an internal octagon indexing did not significantly reduce the strength of the implant connection. Sufficient strength was exhibited, which would indicate this implant-abutment design for anterior as well as posterior edentulous sites.* INT J ORAL MAXILLOFAC IMPLANTS 2003;18:865–872

Key words: *biomechanics, dental abutments, dental implants, Morse taper*

Implant dentistry has revolutionized therapy for edentulous and partially edentulous patients, and successful implant integration has been well documented for patients with those clinical conditions. With the high rate of implant success for edentulous,[1] partially edentulous,[2] and single-tooth restorations,[3–6] the concept of osseointegration and implant therapy has flourished as a predictable treatment modality. Numerous implant manufacturers have emerged to enter the marketplace. Due to advancing technology, and increased patient demand and clinician experience, available implant designs are constantly evolving to meet esthetic and functional requirements.

The biomechanical rationale of endosseous implants has been investigated and researchers have established considerations such as number, distribution, and cantilever forces on implants.[7–9] Even with the knowledge base available, clinicians and patients experience problems. Numerous reports have and continue to reveal technical problems such as screw and abutment loosening.[4,5,10–13] According to McGlumphy, screw loosening occurs when external forces trying to separate the parts exceed the forces keeping them together.[14]

[1]Assistant Clinical Professor, Graduate Prosthodontics, Department of Restorative Sciences, Baylor College of Dentistry, Dallas, Texas.
[2]Professor and Program Director, Graduate Prosthodontics, Department of Restorative Sciences, Baylor College of Dentistry, Dallas, Texas.
[3]Associate Clinical Professor, Department of Restorative Sciences, Baylor College of Dentistry, Dallas, Texas.
[4]Associate Professor, Department of Biomaterials Science, Baylor College of Dentistry, Dallas, Texas.

Reprint requests: Dr Thomas A. Ding, 3600 Gaston Avenue, Suite 1107, Dallas, TX 75246. Fax: +214-823-1370. E-mail: tding@dallasesthetics.com

Implants featuring an external-hex, butt-joint interface have shown an incidence of abutment screw loosening up to 38%.[4,5,15] To overcome some of the inherent problems, solutions such as torque drivers,[15] screw surface technology, platform size, and materials have been investigated to obtain a set preload and greater clamping force.[12,16,17]

Application of a specified amount of torque generates the preload within the screw. Preload is what keeps the screw threads tightly secured to the mating counterpart of the screw. It holds the parts together by producing a clamping force between the screw head and its seat.[12,18] The more torque applied, the greater the screw preload generated. This in turn will cause a greater clamping force and resistance to loosening of the joint, since greater external forces are needed to cause separation of the implant components.[12,14,18–20] When higher tightening torque values are used, greater preload and clamping forces will result; however, the elastic limit of the screw cannot be exceeded. The preload torque should be as high as possible to create a firm contact between the abutment and implant.[20,21]

Increased screw loosening, component fracture, and difficulty in seating abutments in deep subgingival tissues are problems commonly experienced when working with an external-hex connection. To overcome some of the inherent problems associated with an external-hex, butt-joint connection, Sutter and coworkers[22] proposed an 8-degree internal-taper connection, known as the Morse taper, between the implant and abutment. This 8-degree taper with predictable vertical positioning and self-locking characteristics has dramatically enhanced ability to resist bending forces and abutment loosening.[3,6,14,18,19,21] With this predictable vertical positioning, subgingival tissues do not pose the difficulties seen with the external hex, which can require a radiograph to determine whether the abutment is fitted on the hex properly.

Sutter and coworkers presented data that demonstrated the loosening torque to be around 124% of the tightening torque at a level of 25 Ncm; in addition, the loosening torque was 107% of the tightening torque under dynamic loading.[22] With the use of an internal conical implant-abutment connection, Levine and associates[3,6] reported a much lower rate (3.6% to 5.3%) of abutment loosening in comparison to the external hex for single-tooth replacements. Norton showed that the internal conical interface between the implant and abutment significantly enhanced the ability of the dental implant system to resist bending forces.[15,23]

Unlike the external-hex systems, which were traditionally stacked, the ITI Implant System (Straumann, Waldenburg, Switzerland) incorporated an internal conical connection that utilizes an 8-degree tapered, cone-to-screw base that is screwed into the conical portion of the implant.[22,24] In 1992, Wiscott and Belser suggested supplementing the system with an internal design to allow for repositioning of the abutments.[25] In 1999, ITI introduced a new prosthetic system that would expand the range of restorative options without adversely affecting the reliability of the well-proven Morse taper connection, known as the synOcta System.[26,27] The new 2-part implant design contains an internal octagon that is located approximately in the middle of the Morse taper.[26,27]

With the use of the older 2-part ITI implant, the basic seating mechanism is the positive locking and friction seat of the conical abutment. This internal seat led to a friction fit and a much stronger abutment-to-implant connection than that obtained with an external-hex connection.[15,23,28] The new synOcta implant with the internal octagon does indeed give more restorative options to the dentist. Questions have arisen as to whether loss of the Morse taper's intimate fit in the middle third of the implant leads to any loss in mechanical advantages that were present in the previous implant body design. The implant-abutment interface surface area is 31% smaller in the synOcta design that in the previous implant design (16 mm^2 vs 24 mm^2) Straumann has conducted its own investigation to illustrate that because friction is the determining working principle in the internal connection and is independent of the contact surface area, there is no detrimental effect on the Morse taper.[26,27]

In this independent study, 2 different ITI implants with different internal geometry were analyzed: the new ITI synOcta 2-part implant with the internal octagon configuration and the ITI 2-part implant with just the 8-degree internal Morse taper configuration. The purpose of this study was to compare, radiographically and microscopically, both internal connections in 2 separate modes: *(1)* repeated torque/reverse-torque values of each system, and *(2)* ultimate "failure load," ie, the force corresponding to permanent deformation of each system when loaded at a 30-degree off-axis angle.

MATERIALS AND METHODS

Implant Systems

The technique used to test the mechanical characteristics of selected ITI dental implant designs involved the use of 36 implants that measured 4.1 mm in diameter and 10 mm in length. Of these 36

Fig 1a Torque measurement recording.

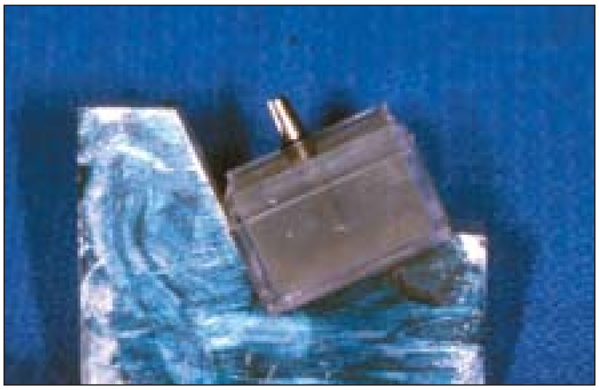


Fig 1b Specimen supported in stainless steel block with an incline of 30 degrees.

implants, 24 were of the new synOcta implant design (043.012S); half of these were paired with a 5.5-mm solid abutment and the other half with a 5.5-mm synOcta solid abutment (048.605). The other 12 implants consisted of the older 2-part solid-screw implant design (042.054S) paired with the 5.5-mm solid abutments (048.541).

A dental surveyor (Ney Company) was used to embed the 36 implants into acrylic resin blocks (Sample-kwick; Buehler, Lake Bluff, IL) that measured 1×1×1 inches. Each block was held parallel to the surveyor platform to ensure that the implant was placed perpendicular to the acrylic resin block. The implant was held with the surveyor and guide screw so that the junction of its roughened surface and the smooth surface of the platform was at the top of the block. The autopolymerizing resin was then poured into the block and allowed to set for 24 hours.

Torque Assay

To determine the torque properties, each implant-abutment pair was tightened to 35 Ncm with the use of a digital torque gauge (Model MG10; Mark-10 Co, Hicksville, NY) at a right angle. After 2 minutes, the torque required to loosen the abutment was measured with the digital torque gauge and the values were recorded (Fig 1a). The abutments were then retorqued, set for 2 minutes, and the process repeated until each sample was tested 3 times to evaluate the changes in the strength of the connection.

One specimen from each of the 3 sample groups was prepared for scanning electron micrographic (SEM) analysis following torque application of 35 Ncm to evaluate the internal abutment/implant surfaces. Additionally, one 2-piece synOcta 5.5-mm solid abutment was hand-tightened and prepared for analysis. Photographs were taken of the area at the abutment/implant body interface to compare and illustrate the internal connection and reduction in surface area of the Morse taper with regard to the synOcta implant design.

Compression Bending

For the compressive bending test, 10 implant and abutment samples from each group were analyzed. Prefabricated ITI plastic waxing burnout sleeves were placed on each abutment, and a crown was fabricated with contours that fit the custom Instron tip (Instron, Canton, MA), ie, 1 crown per test group. The crown had an occlusal-gingival height of 7.5 mm. The test prosthesis was cast with high noble metal (Orion; Degussa/Ney, New York, NY) and cemented with TempBond NE (Kerr Dental, Orange, CA). A stainless steel block was fabricated with an incline of 30 degrees to provide support and resistance against movement of the acrylic resin block (Fig 1b). Once the samples were fixed and aligned in the Instron machine (MTS System, Minneapolis, MN), a compressive load was applied at the incisal edge with a crosshead speed of 0.01 inches/minute until the failure load of the samples was evident. The failure load corresponded to the point on the force versus displacement plot at which permanent deformation began. Upon failure, each sample was removed, and the maximum applied load and the mode of failure were recorded.

SEM

Periapical Kodak Ultra-Speed D film radiographs (Kodak, Rochester, NY) were taken perpendicular to the resin block at 70 kVp. Visual inspection with a light microscope (×50) was used to evaluate the location of the failure or fracture.

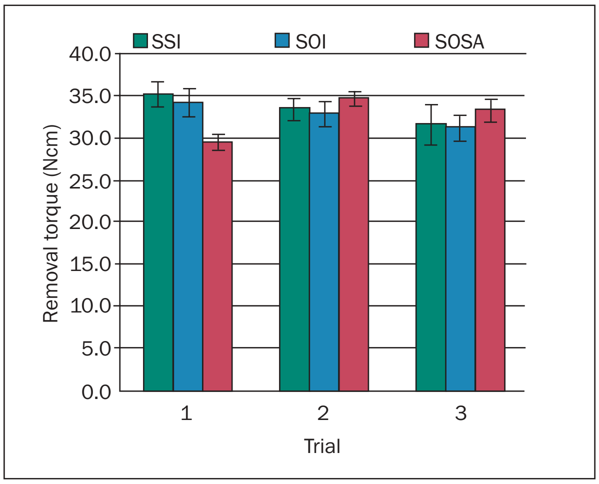


Fig 2 *(Left)* Removal torque. SSI = solid-screw implant with 5.5-mm solid abutment; SOI = synOcta implant with 5.5-mm solid abutment; SOSA = synOcta implant with 5.5-mm synOcta solid abutment.

Table 1 Compressive Bending Values (Lbs of Force)

	Mean	SD
SSI	313.8	14.4
SOI	312.8	20.4
SOSA	281.3[a]	14.1

SSI = solid-screw implant with 5.5-mm solid abutment; SOI = synOcta implant with 5.5-mm solid abutment; SOSA = synOcta implant with 5.5-mm synOcta abutment.
[a]Significantly different than the other two groups at $P < .05$.

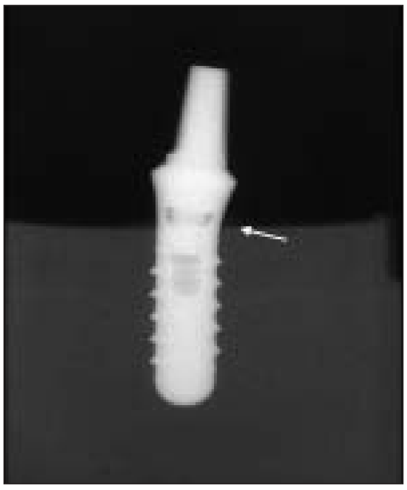


Fig 3a Periapical radiograph of solid-screw implant with 5.5-mm solid abutment illustrating area of bending *(arrow).*

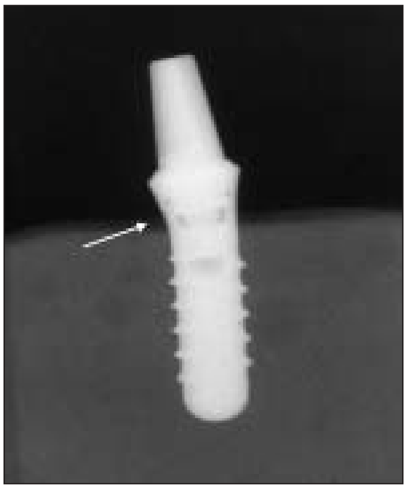


Fig 3b Periapical radiograph of synOcta implant with 5.5-mm solid abutment illustrating area of bending *(arrow).*

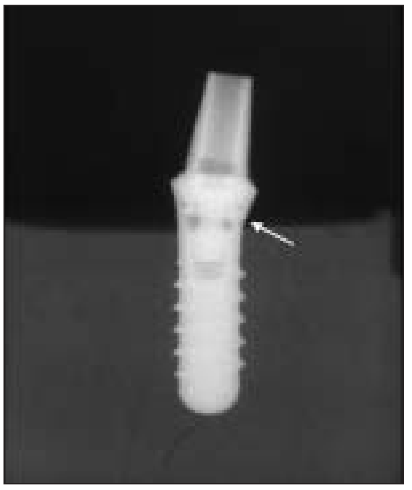


Fig 3c Periapical radiograph of synOcta implant with synOcta 5.5-mm solid abutment illustrating area of bending *(arrow).*

Statistical Analysis

SPSS Statistical Software for Windows (release 9.0, SPSS, Chicago, IL) was used for all statistical procedures. Repeated measures, analysis of variance (ANOVA), and the Scheffé test were used at a significance of $P < .05$ to evaluate the results.

RESULTS

The data resulting from the repeated reverse-torque study are shown in Fig 2. Three measurements for each specimen were performed to evaluate the degree of change that occurred with repeated use. The initial value of the synOcta implant with the 5.5-mm synOcta solid abutment (SOSA) was significantly lower ($P < .05$) than those for both the solid-screw implant with the 5.5-mm solid abutment (SSI) and the synOcta implant with the 5.5-mm solid abutment (SOI). In addition, the second torque sequence was significantly higher than that obtained in the initial sequence for the SOSA ($P < .05$), ie, 34.8 ± 0.8 Ncm versus 29.5 ± 0.9 Ncm.

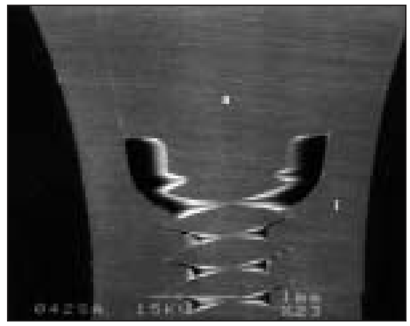
The results of the compressive bending test for the 3 sample groups are shown in Table 1. The ultimate tensile strength of the SOSA apparatus was significantly lower than that of the other setups.

Radiographic evaluation showed that all 3 sample group specimens did indeed remain intact, but all failures occurred because of a bending movement that occurred either at the base of the abutment or at the thinner portion of the implant, as was the case with the synOcta implants (Figs 3a to 3c).

SEM photographs and observations were done on 1 specimen from each group along with the hand-tightened 2-piece synOcta 5.5-mm solid abutment specimen and are shown in Figs 3 to 7.

Fig 4a *(Left)* SEM of solid-screw implant with 5.5-mm solid abutment (×23) showing abutment (a) and implant (i).

Fig 4b *(Right)* SEM of solid-screw implant with 5.5-mm solid abutment (×45) showing abutment (a) and implant (i).



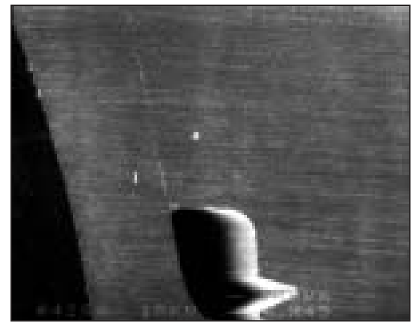
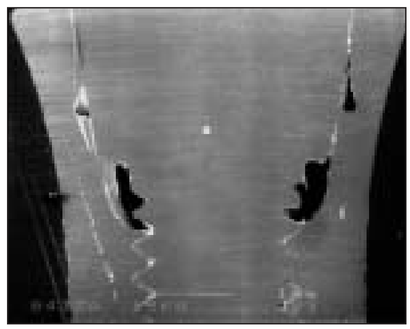
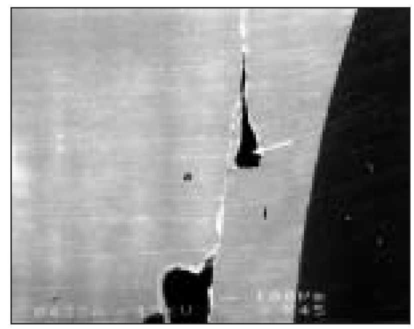


Fig 5a *(Left)* SEM of synOcta implant with 5.5-mm solid abutment (×23) showing abutment (a) and implant (i).

Fig 5b *(Right)* SEM of synOcta implant with 5.5-mm solid abutment (×45) showing abutment (a) and implant (i). Arrow indicates internal octagon indexing space.





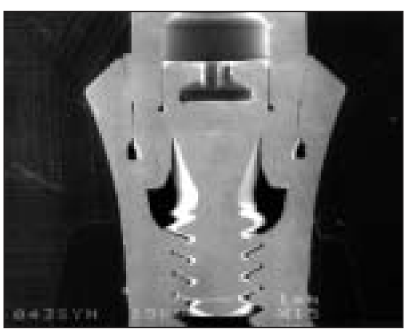


Fig 6a SEM of synOcta implant with synOcta 5.5-mm solid abutment (×15) showing the 2-piece abutment connection.

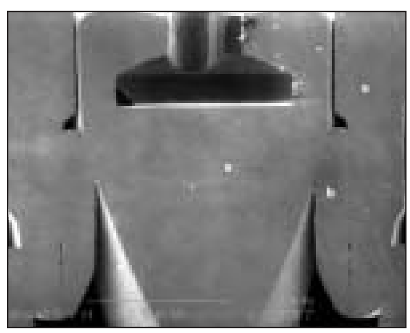


Fig 6b SEM of synOcta implant with synOcta 5.5-mm solid abutment (×37) showing the abutment screw (s), abutment (a), and bearing ring (b).

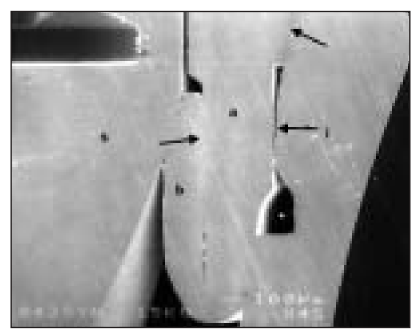


Fig 6c SEM of synOcta implant with synOcta 5.5-mm solid abutment (×45) showing abutment screw (s), bearing ring (b), abutment (a), implant (i), and internal octagon indexing space *(asterisk).* Arrows indicate areas of interface.

Fig 7a *(Left)* SEM of hand-tightened synOcta implant with synOcta 5.5-mm solid abutment (×37) showing the abutment screw (s), abutment (a), and bearing ring (b).

Fig 7b *(Right)* SEM of hand-tightened synOcta implant with synOcta 5.5-mm solid abutment (×45) showing the abutment screw (s), abutment (a), implant (i), and bearing ring (b). Arrow indicates areas of open interface.

DISCUSSION

The main objective of tightening the implant abutment onto the implant body is to generate adequate force, ie, preload, to keep the components together. Many studies have investigated the biomechanics of the implant-abutment connection so as to determine an ample force to withstand screw loosening and minimize complications experienced by the practitioner. Research has shown that an internal connection provides more strength and resistance to bending and screw loosening.[3–8,14–19,21–23,28] The original ITI dental implant utilizes an internal connection, the Morse taper, of 8 degrees, which provides a positive locking and friction seat of the abutment within the implant body. The new implant body design, which allows for indexing and repositioning of the implants and abutments onto a master cast, has undergone changes within the Morse taper internal anatomy.

Under the conditions of this study, the mere alteration of the Morse taper with an indexing design did not affect the strength of the implant-abutment connection when a solid abutment was used. The initial removal torque values for the solid-screw implant (SSI) and the synOcta implant (SOI), when combined with a 5.5-mm solid abutment and torqued to 35 Ncm, were 35.2 ± 1.5 Ncm and 34.1 ± 1.7 Ncm, respectively. Thus, the removal torques were 101% and 97% of the initial torque applied.

In a previous study by Sutter and associates, the loosening torque was shown to be approximately 124% of the tightening torque at a level of 25 Ncm.[22] Although these values were not seen in the present study, it was evident that the force used to torque and clamp the implant and abutment together maintains its mechanical advantage, even with a reduction of 31% in surface area. Since this internal abutment connection with a Morse taper connection relies on friction, surface area is evidently not a determining factor, ie, frictional force = normal force × coefficient of friction. A recent study by Squier and coworkers supported the fact that the indexed internal surface did not have a deleterious effect on the loosening of the solid abutments.[29]

A significant finding in the present study was the fact that the new 2-piece synOcta 5.5-mm solid abutment demonstrated an increased torque removal when a second torque application of 35 Ncm was performed (Fig 2). There is a definite difference when comparing the 5.5-mm solid abutment to the 2-piece 5.5-mm synOcta solid abutment. The 2-piece abutment relies on an internal base screw engaging not only the implant body counterpart threads but also the head of the screw clamping down on the micro-laser–welded bearing ring that is the internal portion of the abutment system (Figs 6a to 6c). The difference in implant-abutment connection strength may be explained by the fact that the base screw obtains a more optimal seat onto the bearing ring, more friction is created, and thus a greater clamping force is provided (Figs 6 and 7). Upon examination of the SEMs of the hand-tightened versus the torqued specimens, it was evident that the areas between the bearing ring and abutment and the abutment/implant interfaces were different. Further studies are necessary to test the biomechanics of this abutment and its connection.

Compression bending studies done on these specimens to evaluate the tensile properties of the implant-abutment connection demonstrated that there is sufficient strength to withstand forces generated by the oral cavity. None of the specimens in the 3 test groups fractured; however, failure occurred as a result of a bending moment, leading to permanent deformation and an unrestorable implant (Figs 3a to 3c). The solid-screw implant with a 5.5-mm solid abutment (SSI) was able to withstand 30-degree off-axis loading forces in the range of 313.8 ± 14.4 lbs, while the redesigned synOcta implant (SOI), with the integration of an internal octagon, demonstrated resistance in the area of 312.8 ± 20.4 lbs. The synOcta implant combined with a 5.5-mm synOcta solid abutment (SOSA) was significantly weaker than the SSI and SOI specimens statistically ($P < .05$), sustaining only 281.3 ± 14.1 lbs, but these values again would sustain biting forces experienced intraorally. Gibbs and colleagues demonstrated that the maximum biting force on average with natural dentition was 162 lbs, and that the normal chewing stroke produced an average force of 58.7 lbs.[30,31] No true screw loosening or fractures were seen, but the implant-abutment connection resulted in a bending of the implant body itself. There seemed to be a change in the site where bending would occur with the change in the implant Morse taper design. With the older solid-screw implant, the bending began at the base of the abutment and the first thread engaging the implant body, while with the synOcta implant, bending initiated near the thinner walls, ie, where the internal octagon configuration is positioned (Figs 3a to 3c). This type of bending failure may be seen by many as a catastrophic failure because the abutment may not be able to be retrieved or replaced, leaving the implant unrestorable.

A compression bending load is the load type that produces the highest stress levels within the implant-abutment interface. The present study demonstrated that even with an alteration within the Morse taper connection, forces in excess of 280 lbs can be withstood. Craig suggested that the assembly should be theoretically able to withstand a maximum bite force of 109 N (25 lbs) in the anterior and 250 N (57.5 lbs) in the posterior regions before overload will occur.[32] Based on these values, all 3 groups in the present study should be strong enough to withstand the compressive forces on a single-tooth implant restoration, whether anterior or posterior.

It must be considered that this was an in vitro test and cyclic loading was not examined. It is well accepted that in vivo performance does indeed differ from an in vitro setting. In this study, the specimens were embedded in an acrylic resin block, which permits little movement; this differs greatly from in vivo conditions because bone and its cortication and trabeculation are involved. Also, loading these specimens at a 30-degree angle reproduces only one of many possible mechanical conditions of the oral cavity. Of clinical significance is that these results can suggest that the restorative clinician loosen the ITI 2-piece synOcta abutment (SOSA) after initial torquing and then proceed to re-torque the abutment to 35 Ncm to achieve a greater clamping force between the abutment and the implant.

CONCLUSION

Under the conditions of this in vitro investigation, the following can be concluded:

1. The initial removal torques of the solid-screw implant with a 5.5-mm solid abutment and the synOcta implant with a 5.5-mm solid abutment were significantly higher than the initial torque removal of the synOcta implant with a 5.5-mm synOcta solid abutment.
2. The second removal torque of the synOcta implant with a 5.5-mm synOcta solid abutment was significantly higher than the initial removal torque.
3. The failure loads for the solid-screw implant with a 5.5-mm solid abutment and the synOcta implant with a 5.5-mm solid abutment were significantly greater than that of the synOcta implant with a 5.5-mm synOcta solid abutment.

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