

***Dental Implant System Design and the  
Potential Impact on Long-Term Aesthetics:  
A Review of the 3i T3™ Tapered Implant***

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Published by **BIOMET 3i™**

# ***Dental Implant System Design and the Potential Impact on Long-Term Aesthetics: A Review of the 3i T3™ Tapered Implant***

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There is a growing appreciation of the importance of establishing and sustaining the aesthetics of implant restorations. Four important factors for achieving this goal are implant primary stability, implant surface, implant-abutment junction geometry, and implant-abutment connection. This article reviews each of these factors as they relate to the design of the **3i** T3 Tapered Implant System and discusses the potential impact these factors can have on long-term aesthetics.

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## **Introduction**

It has been 30 years since Per-Ingvar Brånemark first introduced North American dental researchers to his work with endosseous dental implants. During this time, surgical and prosthetic components, as well as the treatment protocols required for implant therapy, have continued to evolve. At the same time, an evolution in the way clinicians think has also occurred. Clinicians whose initial goal was simply to restore function to edentulous patients soon began working towards making their restorations ever more aesthetic. Attention also shifted to expediting and simplifying treatment.

More recently, the realization has been growing that it is not enough to simply place an implant, wait for it to osseointegrate and then deliver an aesthetic definitive crown. Complex biological processes can sabotage even the most beautiful results over time. Strategies for establishing and ultimately sustaining the aesthetics of implant restorations throughout the course of years and even decades have thus assumed paramount importance.

Many factors contribute to the achievement of aesthetic restorations and that is also true of ensuring that those results are sustainable over time. This article will discuss four important factors in the establishment and sustainability of aesthetic implant restorations. These factors include:

- Implant primary stability
- Implant surface

- Implant-abutment junction (IAJ) geometry
- Implant-abutment connection

## **Implant Primary Stability**

The foundation for aesthetics starts by choosing the correct implant design. When the clinical situation allows, the right implant system can be utilized to begin aesthetically-oriented treatment as early as the day of implant surgery. For example, one can perform a single-stage technique by placing a BIOMET **3i** BellaTek® Encode® Healing Abutment, thereby influencing soft-tissue healing immediately. This single-stage technique minimizes trauma, helps to contour and potentially preserves soft tissues. Another aesthetic option offered by select implant systems is the ability to provisionalize on the day of surgery. This technique provides tissue sculpting benefits along with the additional reward of an instantaneous aesthetic outcome.

A critical factor in the success of these early contouring techniques is the primary stability of the implant system. Excessive micromotion during the early healing process has been well-documented to impede or prevent osseointegration; it may be the most common cause of implant failure. The implant's primary stability must be sufficient for it to resist micromotion until secondary (biologic) stability has been established.<sup>1</sup>

A number of factors enhance the likelihood of achieving primary stability with a given implant system.

For example, the **3i** T3™ Tapered Implant System utilizes depth and diameter-specific drills to create Osteotomes that fit the shape (i.e. minor diameter) of the implants being placed. Implants placed so that their entire surface intimately contacts the full length of the osteotomy have been described as having high Initial Bone-to-Implant Contact (IBIC).<sup>2</sup> Such contact enhances primary stability.<sup>3</sup> Furthermore, the **3i** T3 Tapered Implant design incorporates additional macrogeometric elements to enhance primary stability, including tall, thin threads that penetrate laterally into the bone for secure long-term engagement.

In clinical practice, primary stability is quantified through indirect measures such as insertion-torque or Resonance Frequency Analysis (RFA). Generally, insertion-torque measurements above 35Ncm or RFA readings with an initial stability quotient (ISQ) greater than 65 indicate that the implant's primary stability is sufficient for loading.<sup>4-6</sup>

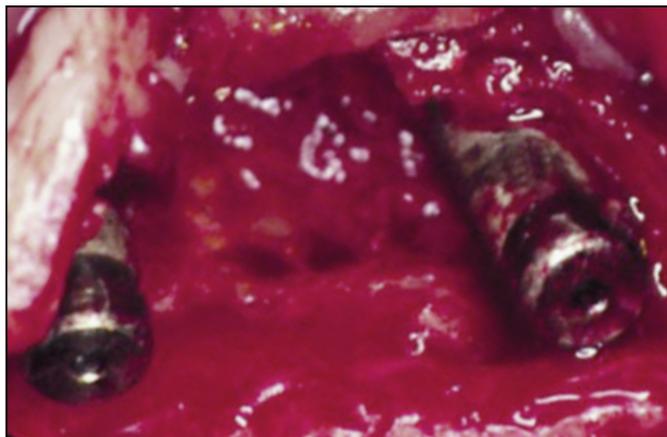
The BIOMET **3i** Tapered Implant design has been shown to regularly meet these primary stability requirements. In a prospective immediate loading study by Östman et al, the investigators placed 139 BIOMET **3i** Tapered Implants in mostly healed sites and reported a mean insertion torque of 53.1Ncm, a mean ISQ of 73.3 and a survival rate of 99.2%.<sup>4</sup> Placing the Tapered Implant into fresh molar extraction sockets, Block reported mean ISQ values of 77 in the mandible, 73 in the maxillae and a survival rate of 97.2%.<sup>7</sup> These results show the high primary stability of the BIOMET **3i** Tapered Implant design in these clinical cases.

An implant system that routinely enables achievement of high primary stability provides the flexibility needed to address patient needs. When accelerated treatment is not applicable, (e.g. when bone quality is poor) good primary stability minimizes micromotion and reduces the risk of non-integration. When clinical conditions are good, primary stability can provide additional benefits, permitting early or immediate provisionalization and/or tissue sculpting to better meet aesthetic demands.

### Implant Surface

One of the earliest strategies for enhancing osseointegration was to roughen the implant surface.

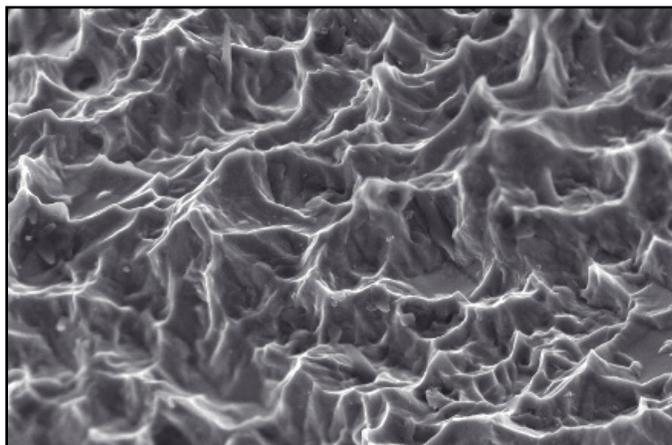
When compared to the relatively smooth surface of turned titanium, a roughened surface was found to increase bone-to-implant contact and improve the strength of the bone-implant interface.<sup>8</sup> In the 1980's, implant manufacturers developed various techniques for roughening implant surfaces, including processes such as titanium plasma spraying and titanium oxide blasting.



**Figure 1.** Patient case demonstrating peri-implantitis around Titanium Plasma Sprayed (TPS) Implants.

While these initial techniques were effective at improving aspects of osseointegration, they often contributed to unforeseen problems. Mucosal and other peri-implant complications were reported for dental implants featuring titanium plasma spray (TPS) and other relatively rough surfaces that extended into the coronal aspects (Fig. 1).<sup>9</sup>

In response to these concerns, BIOMET **3i** refined the implant-roughening process with the introduction of the dual acid-etched (DAE) OSSEOTITE® Surface (Fig. 2).



**Figure 2.** OSSEOTITE Surface at 20,000x magnification.

This surface has a topography that includes 1-3 micron pitting superimposed on a minimally rough surface (Sa, Absolute Mean Roughness < 1.0  $\mu\text{m}$ ).<sup>10</sup> To further reduce the risk of mucosal complications, the OSSEOTITE® Implant was made available in a hybrid configuration that includes the historically proven turned surface on the first 2-3.0mm of the coronal aspect and the dual acid-etched surface on the remainder of the implant body.

Subsequent prospective, multicenter clinical studies of OSSEOTITE Implants have reported cumulative survival rates ranging up to 99.3% and meta-analyses of published data showed no decrease in performance under high-risk conditions.<sup>11-17</sup> Human histologic and histomorphometric evaluations have also demonstrated significantly greater bone-to-implant contact at the OSSEOTITE Surface, as compared to turned surfaces.<sup>18-20</sup>

In 2010, a prospective five-year multicenter, randomized-controlled study was published that compared OSSEOTITE hybrid and fully etched implant configurations for peri-implantitis incidence.<sup>21</sup> Peri-implantitis is a serious long-term complication, generally characterized by chronic soft-tissue inflammation and irreversible loss of supporting bone.<sup>21</sup> The prevalence of peri-implantitis has been reported to be in excess of 12%.<sup>22</sup> In this study, Zetterqvist et al demonstrated that the fully etched surface did not increase the incidence of peri-implantitis as compared to the hybrid design, while providing additional evidence that the fully etched surface reduced crestal bone loss (0.6mm versus 1.0mm,  $p < .0001$ ). This result was consistent with the 2009 one-year results of Baldi et al who also found a statistically significant reduction in bone loss for fully etched implants versus hybrid implants (0.6mm versus 1.5mm,  $p < .02$ ).<sup>23</sup>

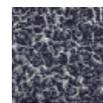
Throughout the years, the clinical successes of OSSEOTITE encouraged continued research into the implant surface and its impact on osseointegration, crestal bone preservation, and peri-implantitis mitigation. These research efforts have culminated in BIOMET **3i**'s newest product introduction: The **3i** T3™ Implant.

In the spirit of the OSSEOTITE Surface, the **3i** T3 Implant surface is more than just another roughened surface. In two distinct regions of the implant, it targets different needs.

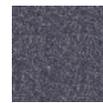
- The coronal aspect of the implant has a microtopography similar to the fully etched OSSEOTITE Implant, consisting of sub-micron features superimposed on 1-3 micron pitting, overlaid on a minimally rough surface topography (Sa < 1.0  $\mu\text{m}$ ).<sup>10</sup>
- From the base of the collar to the apical tip, the **3i** T3 Implant has increased coarse roughness resulting in a tri-level surface. The tri-level surface consists of sub-micron features superimposed on 1-3 micron pitting, overlaid on a moderately rough surface topography (Sa = 1.0 - 2.0  $\mu\text{m}$ ).<sup>10</sup>

Regarding the coronal topography, Zetterqvist and Baldi have provided evidence regarding the fully etched surface's potential impact on peri-implantitis mitigation and crestal bone preservation.<sup>22,23</sup>

Sub-Micron Topography  
Discrete Crystalline  
Deposition (DCD®)  
of Calcium Phosphate  
Nanoparticles



Fine-Micron  
Topography  
Dual Acid-Etched  
(DAE)



Coarse-Micron  
Topography  
Media Blast

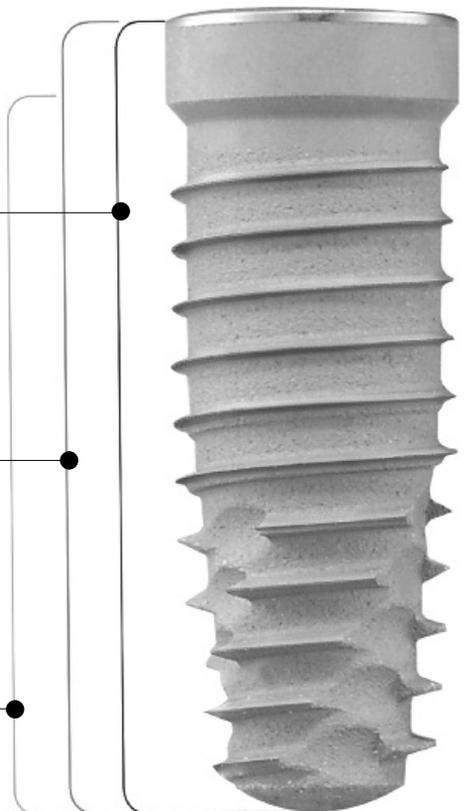
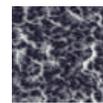
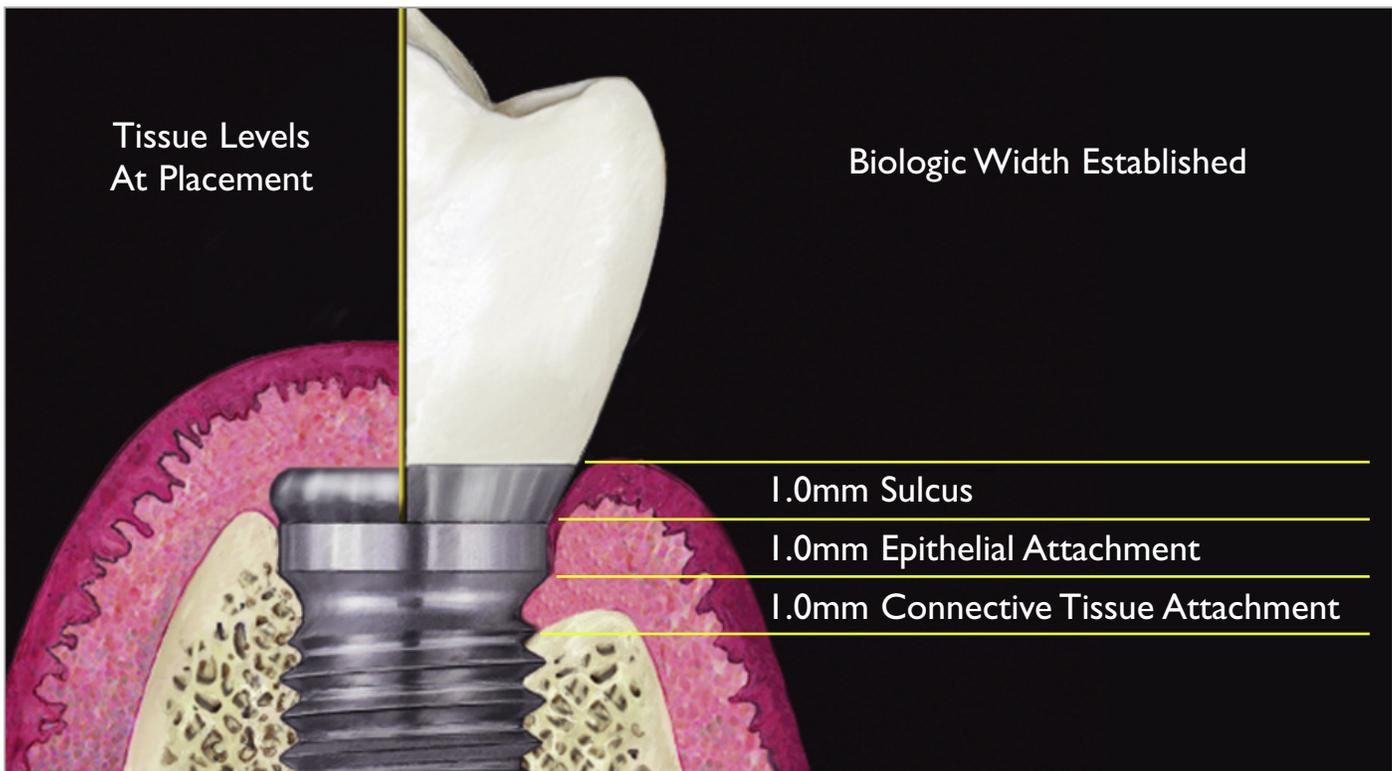


Figure 3. **3i** T3 Tapered Implant.



**Figure 4.** Schematic showing typical bone remodeling on a standard implant following formation of the biologic width.

The apical surface is designed to enhance osseointegration. As such, the included surface features have been researched to assess their potential impacts on de-novo bone formation and the strength of the resulting bone-implant interface.

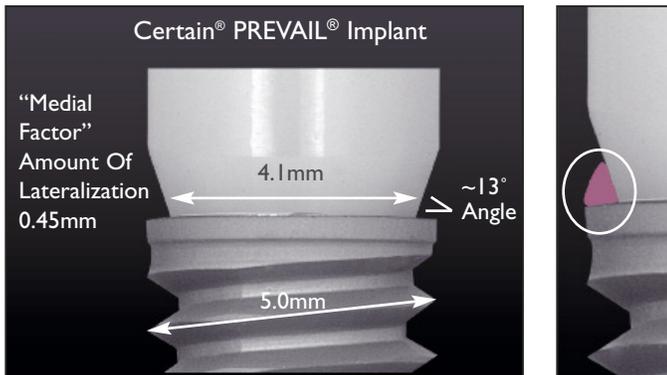
In-vitro studies have evaluated the surface topography effects on bone formation through osteoconduction, including the steps of protein absorption, fibrin clot retention, and platelet interaction.<sup>10,24-27</sup> For example, Davies et al reported that enhanced surface topographies, such as blasted and acid etched, display significantly greater fibrin retention forces than machined surfaces ( $p=.02$ ).<sup>26</sup> Kikuchi et al have documented that micro-topographic surfaces, defined as one which exhibits features in the scale range of platelets (e.g.  $\leq 3$  microns), display greater platelet activation than smoother surfaces.<sup>24</sup>

In addition to osteoconduction research, in-vivo studies also provide information on the individual elements of the **3i** T3™ Implant surface design. The sub-micron topography level has been well researched. Nishimura et al have reported a statistically significant increase in 14-day rat push-in force when adding sub-micron features to a micro-scale topography ( $p<.05$ ).<sup>28</sup>

Mendes et al published consistent results demonstrating a significant increase in 9-day rat tensile strength ( $p<.05$ ).<sup>29</sup> Similar early healing outcomes have been demonstrated in several other publications.<sup>30-32</sup>

The microtopography component (e.g. 1-3 micron pitting) of the **3i** T3 Implant has also been well studied, including push in, pull-out, and reverse torque testing.<sup>33-35</sup> Overall, these studies demonstrated increases in the force required to liberate implants with micron versus turned topographies. For example, Baker et al reported statistical differences in rabbit pull-out strengths starting at three weeks and continuing through the remainder of the study interval (up to eight weeks).<sup>33</sup>

In addition to the sub-micron and micron features, the coarse roughness level has also been explored. Coarse roughness is typically defined by measurements such as Sa (absolute mean roughness). As eluded to earlier, Svanborg et al have defined categories of roughness, including minimally rough ( $Sa < 1.0$  micron), moderately rough ( $1.0 < Sa < 2.0$  micron), and rough ( $Sa > 2.0$  micron).<sup>10,36</sup> Cordioli et al reported no benefit of increasing coarse surface roughness at five weeks in a rabbit reverse torque



**Figure 5.** Schematic of a Certain PREVAIL Implant. The implant abutment junction (IAJ) is medialized or shifted inward.

(RTQ) model, specifically demonstrating that a dual acid-etched surface (minimally rough) had significantly higher RTQ values than grit blasted (moderately rough) and plasma sprayed (rough).<sup>37</sup> Klokkevold et al one month rabbit reverse torque results were consistent with Cordioli when comparing a dual acid-etched and a rough surface.<sup>35</sup> However, Klokkevold's study included additional time points. The researchers subsequently discovered that the group with additional coarse roughness had significantly higher RTQ results at the two and three month time points ( $p < .01$ ,  $p < .002$ ). Klokkevold attributed this difference to the rough surfaces' increased depth of topography and subsequent void volume, which permitted additional bone in-growth for mechanical interlocking.

For dental implants, the surface is critical to establishing and sustaining aesthetic outcomes. To this end, the **3i** T3™ Implant surface represents a significant step forward, with multiple topography levels and features along the implant body designed to influence osseointegration, crestal bone level, and lower the risk of peri-implantitis.

### Implant-Abutment Junction Geometry

A third crucial factor for long-term maintenance of aesthetic restorations is the influence of the implant-abutment junction (IAJ) geometry on the biologic width. The biologic width is the natural seal that develops around any object protruding from the bone and through the soft tissue into the oral environment. It consists of approximately 1.0mm of connective tissue and 1.0mm of epithelium, forming a barrier that protects the bone from bacteria contained in the oral

environment (Fig. 4).<sup>38</sup> When implants are placed and connected to transmucosal abutments, the body reacts by re-creating the required biologic width between the oral environment and bone. If the soft tissues are insufficient, the bone may resorb until an adequate biologic width is re-established.<sup>39</sup>

A discovery that occurred in the early 1990s first raised the possibility that implant design could impact biologic width. This discovery occurred when standard 4.0mm diameter abutments were routinely used to restore 5.0mm and 6.0mm diameter implant designs. Radiographic follow-up of these "platform-switched" implants yielded the surprising finding of greater preservation of the crestal bone.<sup>39</sup> This led to the development of an implant system that incorporated platform switching into its design (PREVAIL Implant), which enabled extensive study of the mechanisms at work (Fig. 5).

A recent systematic review and meta-analysis of ten clinical studies including 1,238 implants found significantly less marginal bone loss around platform-switched implants, as compared to platform-matched ones.<sup>40</sup>

There are many hypotheses on how the platform-switch design impacts the biologic width and subsequent bone level. The primary hypothesis is that the platform switched implant/abutment geometry forms the tissue inward and away from the bone, better sealing off the bone from oral contaminants during normal usage and particularly during component swapping.<sup>41</sup> A related hypothesis is that the biologic width is not strictly a vertical measure but is controlled by the relative surface distance made available by the implant/abutment combination. A platform-switched implant/abutment combination provides additional surface distance through its vertical and horizontal dimensions to establish the required biologic width prior to the bone level being affected.<sup>42</sup> A third hypothesis is that the platform switching geometry influences the biomechanical stress distributions on the residual bone, leading to preservation.<sup>43</sup> A final hypothesis involves the shift of the IAJ inward, mitigating bone inflammation caused by microbial contamination from a poorly sealed IAJ.<sup>44</sup> Ultimately, the reason why platform switching is

effective is most likely the result of one or more of these hypotheses.

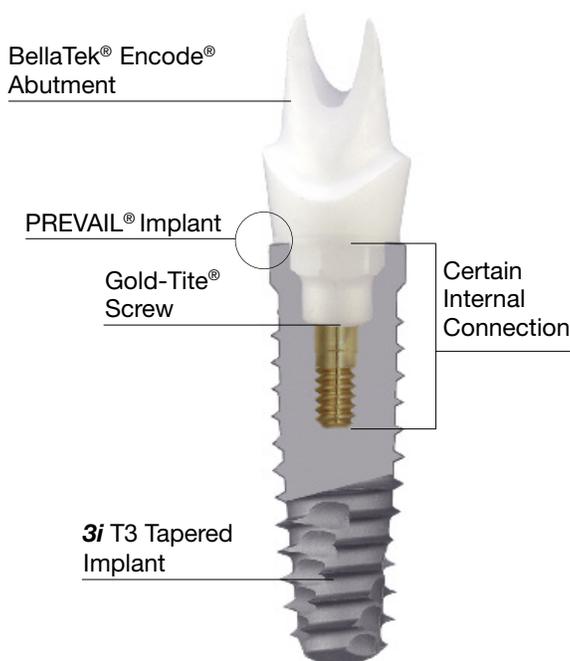
The **3i** T3™ Tapered Implant incorporates integrated platform switching into its design, which has been correlated to the preservation of crestal bone.<sup>40,42</sup> By eliminating or reducing bone resorption at the top of the implant, the papillae and facial gingival marginal tissue remain supported. Tissue support is critical to the establishment and sustainability of functional and aesthetic outcomes.<sup>45</sup>

### Implant-Abutment Connection

A fourth factor that influences immediate and long-term aesthetic outcomes is the implant system connection design. A well-engineered connection will meet user requirements for:

- Ease of use
- Versatility
- Strength
- Stability
- Fit
- Accuracy

Most of these needs correlate with aesthetics. The **3i** T3 Tapered Implant was designed with the Certain® Internal Connection to meet these requirements.



**Figure 6.** Schematic of a **3i** T3 Tapered PREVAIL Implant.

The Certain Connection incorporates several features to enhance its ease of use (Fig. 6). These include a non-mounted design to eliminate steps during surgical placement, color coding of the implant connection and associated restorative components for easy selection, and a patented audible “click” feature confirming component seating. Additionally, this connection offers compatibility with the BellaTek Encode Impression System, which eliminates the need for impression copings and implant-level impressions.

The connection design also includes a 12-position double hex. This serves two related purposes. First, the 12 positions allow the surgeon to place the implant optimally in the prepared osteotomy without indexing the connection (over rotating or under rotating to match a connection point to a buccal landmark). This makes surgical placement easier, as well as allows the implant to be placed with the highest amount of Initial Bone-to-Implant Contact (IBIC), and subsequent primary stability. Second, the 12-position connection provides the restoring clinician with maximum aesthetic versatility. They can more easily compensate for treatment that requires less-than-optimal surgical placement by using stock pre-angled components.

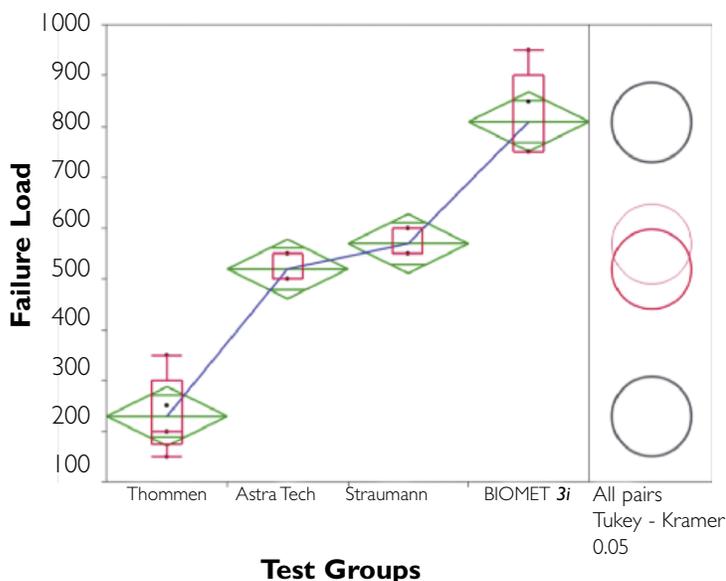
In addition to being easy to use, the implant connection must work synergistically with the overall implant, abutment, and screw designs to provide the strength required for long-term aesthetic performance. To assess system strength, dental implant manufacturers typically test their systems using the standardized test method described in ISO14801, Dynamic Fatigue Test for Endosseous Dental Implants.<sup>46</sup> The standardization of this test permits the comparison of results provided by various manufacturers. Table I displays the fatigue strength of the BIOMET **3i** Certain Implant System relative to three other competitive implants.

Looking beyond strength, the stability and tightness of the implant/abutment connection may also affect aesthetics. A stable, tight implant/abutment interface minimizes abutment micromotion and reduces potential microleakage. Improved performance in these areas has been theorized to reduce the inflammatory processes associated with bone or tissue loss.

Item	Description	Endurance Limit
		N
Ex-Hex Connection Implant	Competitor #1, 3.75mm diameter	185 <sup>47,48</sup>
Internal Connection Implant	Competitor #1, 4.3mm diameter	283 <sup>47,48</sup>
Conical Connection Implant	Competitor #2, 4.1mm diameter	300 <sup>47,48</sup>
XIFNT415	BIOMET <b>3i</b> Tapered, 4.0mm Diameter	377 <sup>48</sup>
XIIOS4315	BIOMET <b>3i</b> PREVAIL®, 4.0mm Diameter x 3.4mm Platform	451 <sup>48</sup>

**Table 1.** Results from fatigue testing of implants based on ISO14801 test method (set-up specified as per ISO14801).

In a recently presented study, Suttin et al assessed the strength and seal robustness of four commercially available implant systems including Thommen Medical (flat on flat connection), Straumann® (conical connection), Astra Tech™ (conical connection) and BIOMET **3i** (flat on flat connection).<sup>49</sup> The results of the study demonstrated the potential advantages of the BIOMET **3i** Certain® Implant connection in terms of microleakage resistance under dynamic load conditions. Figure 7 demonstrates the final failure loads at which each of the samples (n=5 per manufacturer) leaked, fractured, or exhibited a combination of both.



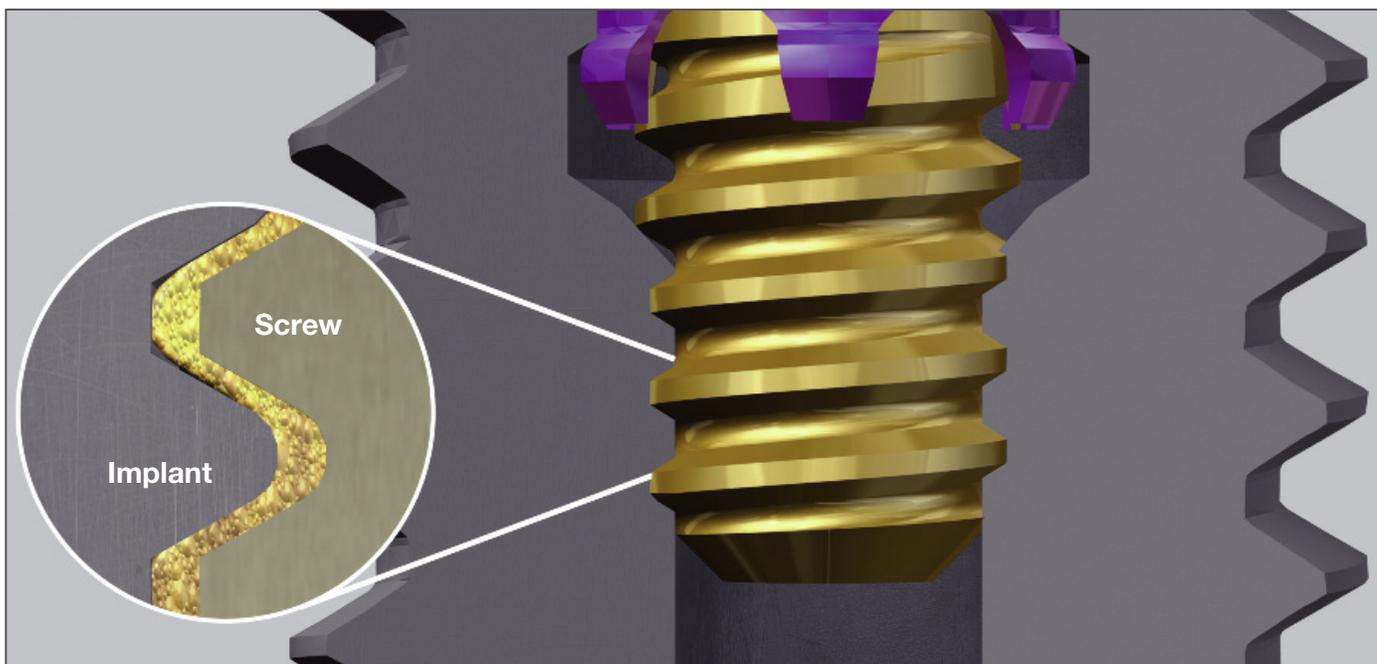
**Figure 7:** Ramped Cyclic Loading.

The Certain Internal Connection microleakage results run counter to the assertions of manufacturers of

implants with conical connections. But not all flat-on-flat implant systems are created equal. The Certain System has been designed with exacting interface tolerances for precise abutment mating and Gold-Tite Abutment Screw technology to maximize clamping forces.<sup>50</sup>

The Gold-Tite® Abutment Screw is coated with a minimum of 40 microinches of 99.9% pure gold. This coating acts as a dry lubricant, reducing the friction between the screw and the implant threads. The dry lubrication permits the screw to stretch, rotating the screw further into the implant, and ultimately pulling downward on the mated component (Fig. 8). The tight clamping of the implant and mating components maximizes the stability of the interface, while reducing the potential for micromotion. This output helps to explain the microleakage resistance of the Certain Implant System.

A final advantage of the Certain Connection is its ability to minimize vertical restorative errors. Such errors may be created through the inaccurate transfer of the seating position through the restorative process, which can result in a definitive prosthesis experiencing improper occlusion, contact error, or a non-passive fit.<sup>51,52</sup> The constant seating position of the Certain Connection eliminates error sources that are known to plague conical interface connections. Dailey et al and Towse et al identified and quantified sources of conical connection error, demonstrating the potential benefits the Certain Connection provides.<sup>51,52</sup>



**Figure 8.** The Gold-Tite® Abutment Screw, coated with a minimum of 40 microinches of 99.99% pure gold, acts as a dry lubricant to reduce friction between the screw and the implant threads, thus permitting the screw to stretch and applying greater clamping force.

As the dental implant community transitions to digital restorative technologies, new sources of error are presenting themselves. In order for this technology transformation to be successful, it is becoming increasingly critical that all participants in the workflow minimize their contributions to the overall error. The **3i** T3™ Implant with the Certain® Connection is leading the way in vertical restorative accuracy, and is subsequently well positioned to meet current and future digital technology demands.

### Clinical Relevance

Patients want and increasingly will expect that their implant-supported restorations look as good over time as they did on the day of delivery. This requires attention to many factors. The implant design can significantly impact the factors required to establish and sustain aesthetics.

The **3i** T3 Tapered Implant System has been engineered to meet these fundamental requirements providing:

- The primary stability necessary for early aesthetic provisionalization and/or tissue sculpting.
- A refined surface design to enhance osseointegration, with no increased risk of peri-implantitis as compared to hybrid implants.

- The system strength for long-term aesthetic function.
- An implant/abutment geometry and related connection features designed to preserve bone at and around the implant to provide support for the development and maintenance of soft tissue.
- A highly accurate connection well positioned to meet current and future digital restorative needs.

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<sup>†</sup>Dr. Richard J. Lazzara has a financial relationship with BIOMET **3i** LLC resulting from speaking engagements, consulting engagements and other retained services.

Zachary Suttin and Ross Towse prepared this analysis while employed at BIOMET **3i** LLC.

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