Clarence Tam, HBSc, DDS (Canada)
Private Practice in Restorative Dentistry at Cosmetic Dental
126B Remuera Road
Remuera, Auckland 1050

NZDA News, July 2009

# ***Implant Variables for Clinical Success: Increasing Predictability***

Threaded titanium implants have been extensively used and proved in the predictable dental rehabilitation of edentulism since the conception of the endosseous root-form implant by Dr. P.I. Branemark in 1952. Indeed, many long-term results indicate that the threaded design facilitates the near-ideal distribution of mechanical forces in bone. With this threaded design, manufacturers have devised variations in implant anatomical design, material choice, surface treatments as well as dimensions to increase the strength and clinical applicability of its already almost magnetic cohesion to bone. As this article will demonstrate, clinical success is predicated upon implant and host variables working in conjunction to disturb as little as possible the biological matrix. There is no hole-in one.

The protocol for the achievement of osseointegration in implant therapy has evolved from the traditional two-stage surgery to single-stage surgeries with delayed or immediate loading supporting single teeth, fixed partial dentures, removable partial dentures, overdentures, and maxillofacial prostheses. The speed of bony contact and healing in osseointegration have been optimised through nanotechnology in the modification of the implant-bone interface. Some of these surface treatments that are available are: titanium plasma-sprayed, hydroxyapatite (HA)-coated, titanium dioxide-blasted, as well as acid-etched surfaces. In general, by increasing the surface area of the implant, the stronger the ultimate bond to bone. This technology has led to an increased success rate, a smaller healing window, and faster functional rehabilitation of the patient.

## ***Key Components for Osseointegration***

### Surface Treatments

The need for more predictable osseointegration led to the modification of machined titanium surfaces. Titanium dioxide blasting and modification of surface characteristics by fluoride was the global-first for dual physical and chemical modification of an implant surface by nanotechnology by Astra Tech. In 2005, Aalam *et* al[1] could not find differences in clinical success between titanium surfaces modified with anodized oxidation or dual-acid etching. Anodized oxidation (Ti-Unite, Nobel Biocare) of the Grade 4 titanium surface was achieved in 2000. Using a proprietary microengineering process, the innate surface oxide film is induced to grow in a controlled manner, ultimately giving the surface a porous texture, thus increasing the surface area. The result is a highly crystalline and phosphate-rich oxide layer lacking sharp transitions with open pores. Dual acid-etching (Osseotite, 3i) of the implant surface is achieved by sequential application of hydrochloric and sulphuric acid, again forming an irregular surface topography seductive to osteoblasts. The increase in surface area via sandblasting and acid-etching or when porous titanium surfaces are created is commensurate to the highly-efficient integration and higher resistance to shear forces compared to machined controls.[7]

### Macroscopic Grooves

In 2005, Hall *et al*[6] studied the effect on osseoconduction of macroscopic grooves incorporated in the surface of the implant. Research has well-proven the influence of thread design at the millimetre level and the modification of surfaces at the micrometer level. The intermediate void of the sub-millimetre range on osseoconduction and bone development spurred the study to focus on implant structures in the 50-200 micron range positioned on the thread flank of oxidized titanium implants. Two size variables were tested: 110µm (S1) and 200µm (S3), with the removal torque test figure 30% higher for S1 (statistically-signifiant) and 8% higher for S3 (not statistically-significant) compared to machined controls. The addition of the macroscopic grooves increased the surface area by 10% for both S1 and S3 grooves. It may well be that grooves with dimensions similar the size of the cells studied could stimulate cell migration within the groove, leading to preferential bone development as shown in this study. Further research is required in this area, where the present trend towards immediate implant loading requires efficient implant integration kinetics.

## Implant Anatomical Choices

Clinical success in osseointegration is dependent on several variables, such as primary stability – influenced by implant design and surface characteristics, adherence to strict surgical protocols, host factors and biocompatibility. Traditionally, titanium has been used for endosseous root form implants, endosseous blade implants, sub-periosteal implants, transosseous implants and mini (transitional) implants. Zirconia ceramics are also biocompatible and have mechanical properties that are attractive for use in implant therapy.

## Zirconia Implants

One of the drawbacks to the use of titanium is its inherent dull gray colour, which poses a problem in cases with a thin, fragile biotype. Zirconia has superior fracture toughness and high flexural strength. Sennerby *et al*[11] in 2005 studied the difference in removal torque values for machined zirconia implants versus surface roughened (ZrA and ZrB). Results demonstrate a 4-5 fold greater value for the surface modified zirconia variables compared to machined control. Indeed, the "rougher" surface topography of ZrA exhibited a removal torque value virtually equal to that of Ti-Unite (higher than Ti-Unite: not statistically-significant). More research is required in this area.

## Miniature Implants

The miniature or micro implant is a paradigm shift in implant anatomy that strives to take advantage of titanium's predictable biocompatibility and osseointegration. Many of the convenience-based offerings tempt practitioners to place these in clinical situations that are prone to high failure rate. Mini implants are not a panacea. They work well when used for particular applications in a very restricted clinical focus. The mini implants, manufactured by various companies, typically come in a diameter value that is less than that of conventional implants, but feature increased implant lengths on average. This is necessary since primary stability of these implants relies on bicortical stabilization, according to manufacturer's protocol. Ideal placement of the regular thread implants are in Type I bone, however a "MAX" thread has been fabricated by 3M IMTEC for use in Type II and III bone applications. Clinical concerns include possible thread depth since the diameter is minimal as well as long-term prognosis for these special implants, despite their treated surfaces. Surface area is also significantly less compared to conventional implants; important in implant-bone anchorage. Mini implants have been widely used traditionally as temporary anchorage devices (TADs) in orthodontics, and continue to be used effectively in this field, along with lower denture stabilization, where they have become an economical method of increasing the stability of the lower floating complete denture. Areas of ideal application include atrophic mandibular anterior alveolar ridges, where pain or cost factors rule out bone grafts and full body implants. Or do they?

Are shorter conventional implants any worse at integrating in bone and maintaining their strength of osseointegration? In 2003, Tawil *et al*[13] followed 269 short machined implants (Nobel) with implant sizes ranging from 6mm to 10mm. Fixture diameters used were 3.75mm, 4mm and 5mm. They found no significant difference in success of osseointegration over a 12-to-92 month period between implant length variables or implant diameters. They did, however, note a greater failure rate of implants placed in the maxilla vs. mandible. Winkler *et al*[15] (2000) discovered that there was less mean stability amongst the 3mm range diameter implants and 4mm range diameter implants tested. A significant difference of survival of 66.7% for the 7mm implant length was observed compared to 94.6% for the 16mm implants in this prospective, randomized, controlled clinical trial of 2917 implants. The only long-term study available specific to miniature implants at this date was performed by Shatkin *et al*[12] (2007), where they retrospectively observed a 94% success rate of 2514 mini implants placed.

It is clear that the rehabilitation of the dentition presents many options and challenges. The restoration of the posterior maxilla presents a constant challenge in the face of pneumatized sinuses and deficient posterior alveolar ridges. Placement of short, conventional implants for restorative goals is one option that reduces the need for augmentation procedures. One argument against shorter implants is the unideal implant length: clinical crown ratio, which may increase vertical bone loss around the fixture. Renouard *et al*[10] (2005) found contrary to this, where they reported a 94.6% cumulative survival rate for their study of 6-8.5mm implants placed in severely-resorbed maxilla. They found that of the 5 failures in their 96 implant group, 4 were of the machined surface group, and 1 was of the oxidized surface. Thus, it is becoming clear that it is desirable to place the maximum length and girth of implant fixture as possible within the confines of the bony anatomy. Predictability can also be increased by using an implant system with a modified surface conducive to bony migration and formation.

## **<u>The Key to Sustained Esthetic Success</u>**

True esthetic success is the achievement of soft and hard tissue integration with the implant restoration as well as the maintenance of biological matrix over time. This is key, because loss in either soft or hard tissue integration will have an effect on the other. Loss in soft tissue from traumatic toothbrushing exposing the fixture head will lead to a corresponding decrease in the height of the marginal bone, producing a lower implant:anatomical crown ratio than before. In the same way, a decrease in marginal bone height through resorptive processes will lead to soft tissue decrease, often opening up undesirable interproximal black triangles. Through patient home-care instructions, we can minimize their iatrogenic oral hygiene damage, but we must also be cognisant of the effects that implant placement has on marginal bone height over time.

Articles generally describe acceptable marginal bone loss (MBL) of implant systems to be 1mm in the first year of loading, and 0.2mm annually for each year following, plateauing at an average bone loss of 1.5mm (cumulative) at the end of a five-year period (Standard set in 1986). In researching different implant systems, Glauser *et al*[5] (2007) reported a stable marginal bone height of approximately -1.3mm from 12 to 60 months following immediate loading of Nobel Biocare TiUnite implants placed in soft bone. This follows in the vein of predictability, where even with immediate loading in Type III bone, optimal results are attained by selecting an implant fixture with a modified surface that is dimensionally-suited for the target volume of bone.

Cooper *et al*[3] (2001) performed a prospective, randomized controlled clinical trial investigating rapid loading of Astra Tech TiOBlast implants within 3 weeks of implant surgery. A success rate of 96.2% was observed. Rapid loading is based on the fact that woven bone formation may occur in as soon as weeks following implant placement, and thus rapid loading may have positive stimulatory effects on bone formation, given that primary stability has been achieved and maintained. Wennstrom *et al*[14] (2005) in their five-year prospective investigation of Astra Tech implants placed in periodontitis-susceptible subjects reported a cumulative marginal bone height loss for machined Astra Tech implants of 0.33mm and 0.48mm for TiOBlast-treated surfaces (not statistically-significant). This difference in marginal bone height maintenance between machined and treated surfaces was also noted by Aalam *et al*[1] (2005), where the greatest difference in crestal bone height was observed between machined and TiUnite surfaces. They proposed that the reason for this disparity was due to the roughness of the treated surface extending to the most coronal aspect of the implant; possibly associated with bacterial colonization.

However, it has been well demonstrated that a roughened implant surface has a stronger initial stability and anchorage and a more intimate bone-implant interface compared to a machined or smooth surface (Glauser *et al*, 2001, Quahash, M. *et al*, 2002). Crestal bone maintenance may be partly or completely responsible for the maintenance of papilla form or even "rebound." Norton *et al*[8] (2004) placed Astra Tech implants in edentulous mandibles. In this study, only 67.5% of the implants exhibited marginal bone loss (MBL), with the mean MBL being 0.40mm after 15.7 months in function. Interestingly, bone was recorded at or even above the implant-abutment (platform-shifting) junction in greater than 1/3$^{rd}$ of the implants. Both the Cooper and Norton studies refute the fact that the abutment-implant interface or microgap is a negative contributing factor on the marginal bone height.

With this in mind, we turn our attention to the neck of the implant fixture, or the area that strives to be continguous with and as least disruptive to the marginal bone as possible. Wolff's Law states that the bone will remodel itself according to the forces or load placed on it. It is well known that excess stimulation of bone will result in focal necrosis. Hence, a bevelled design on the coronal cavosurface is optimal, both from a focal force-minimizing design, as well as facilitating a concave abutment-fixture junction, which is ideal for soft tissue ingress and stability. Thus, it is certainly a delicate task balancing sufficient force for optimal anchorage in lamellar bone, and yet transferring the bulk of the force into the deeper regions of bone. Obtaining maximum cortical anchorage lends the question of what design is optimally osseoconductive? That is, which design lends to the most efficient colonization of the critical coronal section by osteoblasts?

Bae *et al*[2] (2008) studied three implant neck designs: machined or "turned neck" (TN), microthread (MT) (coronal 2mm were inundated with a 400micron thread pitch), and microgroove (MG). The microgroove design comprised a coronal 0.5mm of turned surface before transitioning apically to microgrooves of 8micron and 12 micron pitch (laser-etched), respectively. Bone implant contact was found to be significantly greater for the MG variety compared to TN, with MT showing intermediate values. The lowest marginal bone loss figure also belonged to the MG group, again with MT exhibiting intermediate values. With Masson's trichrome staining, two interesting observations were made: Firstly, osteoblast nuclei were observed in the 8micron groove. This can be attributed to the cell culture tests, which also showed an accelerated growth rate of osteoblasts producing bone in the direction of the grooves. Secondly, on the TN surface, soft tissue response showed parallel orientation of fibroblasts and collagen fibers, similar to that in scar tissue. However, the MG surface exhibited a soft tissue orientation or "reaction" that exhibited irregular and disturbed patterning of fibroblasts and collagen. This observation was echoed in that of Kim *et al*[7](2006). It may well be that this irregularity is the precursor for a more robust and sustained gingival adaptation to the implant surface, thereby minimizing irritation to the alveolar crest.

## Conclusion

The general criteria for implant osseointegration has always been comprised of primary and long-term stability, stable long-term marginal bone height, lack of pain or discomfort, lack of peri-implant rarefying osteitis, lack of implant mobility, and lack of soft tissue pathology or abnormalities. Since this last feature has a direct impact on long-term patient esthetics, particular attention should be paid to the selection of an implant system that has the least amount of aggregate marginal bone loss as evidence by the literature. Maintenance of crestal level is the foundation for sustained soft tissue support. Paradoxically, it cannot be more true that microfeatures are essential to create and sustain macrofeatures such as gingival and bone.

As the implant market inundates us with variations and claims of superior fixture design, we must be ever-cognizant of principles driven by science that convey to us the best chance of clinical success. No longer is predictable esthetics only a function of atraumatic surgical placement, but ever more so a feature of fixture design. In today's evolving dental realm, nanotechnology in surface modifications are allowing us to place implants with ever-increasing ease and predictability of success. Although exciting, it is just as important to temper our enthusiasm with a constant reminder of the basic tenets of implantology. With science pushing the envelope of what can be delivered to our patients, we should challenge what has been accepted as the norm, and strive to harness implant technology to disturb, as little as possible, the biological matrix.

**References**


1) Aalam, A-A, Nowzari, H. Clinical evaluation of dental implants with surfaces roughed by anodic oxidation, dual acid-etched implants and machined implants. *Int J Oral Maxillofac ImplantI* 2005; 20:793-798.
2) Bae, H.E.K., Chung, M-K, Cha, I-H, Han, D-H. Marginal tissue response to different implant neck designs. *J Korean Acad Prosthodont* 2008;46(6):602-609.
3) Cooper, L., Felton, D.A., Kugelberg, C.F., Ellner, S., Chaffee, N., Molina, A.L., Moriarty, J.D., Paquette, D., Palmqvist, U. A Multicenter 12-month evaluation of single tooth implants restored 3 weeks after 1-stage surgery. Int J Oral Maxillofac Implants 2001 Mar-Apr;16(2):182-92.
4) Glauser, R., Portmann, M. Ruhstaller, P., Lundgren, A.K., Hammerle, C., Gottlow, J. Stability measurements of immediately loaded machined and oxidized implants in the posterior maxilla. A comparative clinical study using resonance frequency analysis. *Appl Osseointegration Res* 2001; 2:27-9.
5) Glauser, R., Zembic, A., Ruhstsaller, P, Windisch, S. Five-year results of implants with an oxidized surface placed predominantly in soft quality bone and subjected to immediate occlusal loading. *J Prosthet Dent* 2007; 97(Suppl):79-85.
6) Hall, J., Miranda-Burgos, P., Sennerby, L. Stimulation of Directed Bone Growth on Oxidized Titanium Implants by Macroscopic Grooves: An In Vivo Study. *Clin Implant Dent Relat Res* 2005; 7: S70-S81.
7) Kim, H., Murakami, H, Cehroudi, B., Textor, M., Brunette, D.M. Effects of surface topography on the connective tissue attachment to subcutaneous implants. *Int J Oral Maxillofac Implants* 2006; 21:354-65.
8) Norton, M.R. A 1-to-2-year follow-up of immediately-restored TiOBlast single-tooth implants. Technique and results. *Int J Oral Maxillofac Implants* 2004; 19(2):274-81.

9) Quahash, M., Wikesjo U.M, Thomson, R.C., Cook A.D., Wozney J.M, Hardwick, W.R. Surface etching improves dental implant osseointegration in newly formed and native bone. *J Dent Res* 2002; 81:IADR-Abstract 4000.
10) Renouard, F., Nisand, D. Short Implants in the Severely-Resorbed Maxilla; A 2-year Retrospective Clinical Study. *Clin Implant Dent Relat Res* 2005; 7:S104-S110.
11) Sennerby, L, Dasmah, A, Larsson, B. Iverhed, M. Bone Tissue Responses to Surface-Modified Zirconia Implants: A Histomorphometric and Removal Torque Study in the Rabbit. *Clin Implant Dent Rel Res* 2005; 7:S13-S20.
12) Shatkin, T.E., Shatkin, S., Oppenheimer B.D., Oppenheimer, A.J. Mini dental implants for long-term fixed and removable prosthetics: a retrospective analgysis of 2514 impalnts placed over a five-year period. *Compend Contin Educ Dent* 2007 Feb; 28(2)92-9; quiz100-1.
13) Tawil, G., Younan, R. Clinical evaluation of short, machined implants followed for 12 to 92 months. *Int J Oral Maxillofac Implants*. 2003; 18: 894-90.
14) Wennstrom, J.L, Ekestubbe, A., Grondahl, K., Karlsson, S., Lindhe, J. Oral rehabilitation with implant-supported fixed partial dentures in peridontitis-susceptible subjects: a 5 year prospective study. *J Clin Periodontol* 2005; 32(6):567-74.
15) Winkler, S., Morris, H.F., Ochi, S. Implant survival as related to length and diameter. *Ann Periodontol 2000; Dec 5(1):22-31.*