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Osseodensification outperforms conventional implant subtractive instrumentation: A study in sheep

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ABSTRACT

Osseodensification is a surgical instrumentation technique where bone is compacted into open marrow spaces during drilling, increasing implant insertion torque through densification of osteotomy site walls. This study investigated the effect of osseodensification instrumentation on the primary stability and osseointegration of as-machined and acid-etched implants in low-density bone.

Six endosteal implants were inserted bilaterally in the ilium of five sheep totaling 60 implants ($n = 30$ acid-etched and $n = 30$ as-machined). Each animal received three implants of each surface. The osteotomy sites were prepared as follows: (i) subtractive conventional-drilling (R): 2 mm pilot, 3.2 mm and 3.8 mm twist drills; (ii) osseodensification clockwise-drilling (CW), and (iii) osseodensification counterclockwise-drilling (CCW) with Densah Burs (Versah, Jackson, MI, USA) 2.0 mm pilot, 2.8 mm, and 3.8 mm multi-fluted tapered burs. Insertion torque, bone-to-implant contact (BIC) and bone-area-fraction occupancy (BAFO) were evaluated. Drilling techniques had significantly different insertion torque values (CCW > CW > R), regardless of implant surface. While BIC was not different as a function of time, BAFO significantly increased at 6-weeks. A significantly higher BIC was observed for acid-etched compared to as-machined surface. As-machined R-drilling presented lower BIC and BAFO than acid-etched R, CW, and CCW. New bone formation was depicted at 3-weeks. At 6-weeks, bone remodeling was observed around all devices. Bone chips within implant threads were present in both osseodensification groups. Regardless of implant surface, insertion torque significantly increased when osseodensification-drilling was used in low-density bone. Osseodensification instrumentation improved the osseointegration of as-machined implants to levels comparable to acid-etched implants inserted by conventional subtractive-drilling.

1. Introduction

Endosseous dental implants have been used as a predictable treatment option for the rehabilitation of partial and complete edentulism with high long-term survival rates [1,2]. Osseointegration is defined as the direct anchorage of an implant by the formation of bony tissue around it without growth of fibrous tissue at the bone-implant interface [3]. It is achieved after surgical placement of an implant through bone modeling-remodeling processes around the metallic device [4,5].

An essential aspect of osseointegration is implant primary stability, which is directly related to bone density [6,7], surgical drilling protocol [8], implant surface texture, and geometry [9]. Primary stability is the mechanical bone-implant interlocking that only takes place upon successful fixation of an implant, and is essential for bony fixation because it prevents excessive implant micromovement [10]. Machined implants are known to achieve predictable osseointegration specially in areas of optimal bone density [11]. Hence, dental implants have adopted over the years more aggressive thread designs, specific drilling protocols and roughened surfaces to optimize primary stability and osseointegration in areas of reduced bone density [12]. Once cell-mediated remodeling takes place, primary stability decreases over time in benefit of the secondary stability, which is characterized by bone-implant anchoring

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due to new bone formation over time resulting from bone apposition [12].

Despite the higher levels of primary and secondary stability observed in low bone density [13], textured implant surfaces have shown one main concern compared to machined surface implants. Some textured implant surfaces seems more prone to bacterial colonization and disinfection of contaminated surfaces is more challenging, with reports showing more peri-implant bone loss for rough (1.04 mm), compared to minimally rough implant surfaces (0.86 mm) [14,15]. While peri-implantitis is of multifactorial origin [16], it is prudent to attempt to prevent peri-implantitis by controlling all known potential systemic and local etiologic factors [17,18]. Therefore, given the positive long-term results of as-machined implant surfaces, the use of surgical instrumentation strategies targeted at improving early host response, specially in areas of low bone density, remains open to further development.

Once primary stability is assured, bone remodeling becomes vital for secondary stability establishment as it can be directly related to patient factors and implant surface characteristics [19], such as: surface energy, composition, topography and roughness [20,21]. Machined implant surfaces represents the starting point of implant surface design and it has been used for decades according to classical protocols in which several months were required for osseointegration [22]. Improving implant surface biocompatibility and osseoconductive properties through topographic pattern modifications has been shown to increase not only the bone-implant contact but also biomechanical interaction, resulting in accelerated bone healing and bone apposition rate, and consequently, earlier biological fixation [23].

Drilling technique is another major aspect to be considered when primary stability prompt establishment is expected. Several surgical techniques aiming to increase the primary stability, particularly in low-density bone have been published [24–26]. However, all of them compare subtractive drilling activity performed under the assumption that bone must be removed and excavated. Increased stability may be achieved with various degrees of under preparation of the osteotomy. In general, the combination of increasing implant diameters with reduced osteotomy dimensions result in proportionally increased insertion torque levels during implant placement [27,28].

On the other hand, osseodensification drilling technique is based on the concept of a non-subtractive multi-stepped drilling process through burs that allow bone preservation and autografting compaction along the osteotomy wall [29]. The densifying bur presents a cutting chisel and tapered shank allowing it to progressively increase the diameter as it is moved deeper into the osteotomy site, controlling the expansion process. Also, drilling can be operated in both counterclockwise (CCW) and clockwise (CW) rotation directions at high drilling speeds. The counterclockwise drilling direction is more efficient at the densification process and is utilized in low-density bone, while the clockwise drilling direction is suitable for higher-density bone [30]. Osseodensification drilling provides an environment that enhances primary stability due to compaction auto grafting and the presence of residual bone chips [29–31]. Furthermore, besides improved primary stability, bone densification may accelerate new bone growth through osteoblasts nucleating on the instrumented bone [30,32].

The effect of osseodensification drilling techniques comparing as-machined and surface textured implants has not yet been determined. Consequently, the quantification of the biomechanical and biological basis is warranted in order to evaluate if there is synergism between surgical technique and implant surface texture. The objective of this study was to evaluate the effect of osseodensification on the primary implant stability and progression of osseointegration (3 and 6 weeks) of as-machined (M) or surface textured (grit blasted/acid-etched) (A) dental implants.

2. Materials and methods

A total of 60 conic shaped implants (Ti-6Al-4 V) presenting progressive power threads, 4.0 mm in diameter and 10 mm in length (Emfils D2, Itu, SP, Brazil), were included in the present study. The surfaces included in the present study comprised two different groups: as-machined (M) and grit-blasted/acid-etched (A) [27]. The surface texture was achieved by blasting the surface with aluminum oxide followed by dual acid etching [33]. The implants were sterilized by gamma-radiation.

2.1. Preclinical in vivo model

This *in vivo* study was performed according to the ethical approval from the Institutional Animal Care and Use Committee under ARRIVE guidelines. A translational, large preclinical animal model was chosen. Also, aiming to increase the statistical power and decrease the number of animals, the iliac crest of the sheep hip model was used. Due to animal size, all experimental groups were nested within each subject. Five female sheep weighing approximately 120 pounds were used in the study. Six implants were inserted into the ilium of each animal, bilaterally, resulting in a total of 60 implants ($n = 30$/group; as-machined and acid-etched). While samples that remained *in vivo* for 3 weeks were placed in the left side, the right side consisted of implants for 6 weeks evaluation.

Prior to surgery, anesthesia was induced with sodium pentothal (15-20 mg/kg) in Normasol solution into the jugular vein of the animal and maintained with isofluorane (1.5–3%) in O_2/N_2O (50/50). ECG, SpO_2, end tidal CO_2, and body temperature with a circulating hot water blanket for regulation were used to monitor animals. The surgical site was shaved and treated with iodine solution prior to the surgery. First, an incision of approximately 10 cm was made along the iliac crest, followed by dissections of fat tissue until muscular tissue was reached. Aiming ilium bone exposure, dissection of muscular plane with sharp dissection and the application of a periosteal elevator was performed. Three different osteotomy techniques were conducted: (i) subtractive regular drilling (R) in a 3 step series of a 2.0 mm pilot, 3.2 mm and 3.8 mm twist drills; (ii) clockwise drilling (CW) with Densah Bur (Versah, Jackson, MI, USA) 2.0 mm pilot, 2.8 mm, and 3.8 mm multi fluted tapered burs; and (iii) osseodensification counterclockwise drilling (CCW) with Densah Bur (Versah, Jackson, MI, USA) 2.0 mm pilot, 2.8 mm, and 3.8 mm multi fluted tapered burs. Drilling was performed at 1.100 rpm under saline irrigation. To minimize location bias, experimental group distribution was interpolated as a function of the animal subject, allowing the final comparison of the same number of as-machined and acid-etched implants placed in sites 1 through 6 by R, CW, and CCW surgical drilling at both 3 and 6 weeks (Fig. 1). The insertion torque of each implant was performed to the cortical level and the values were measured and recorded using a digital torquemeter (Tohnichi STC-G, Tohnichi, Japan). Layered closure with nylon 2–0 for skin and Vicryl 2–0 for muscle was performed. Cefazolin (500 mg) was intravenously administered pre-operatively and post-operatively. After recovery, food and water *ad libitum* was offered to the animals. Then, the animals were sacrificed by anesthesia overdose and samples were retrieved by sharp dissection.

2.2. Histologic procedures and histomorphometric analysis

The process for histological and histomorphometric analyses comprised step-by-step dehydration in ethanol and methyl salicylate, followed by a final embedding in methylmethacrylate (MMA). According to a pre-established methodology [34], non-decalcified histological sections were prepared: 300 μm thickness samples were cut using a slow-speed precision diamond saw (Isomet 2000, Buehler Ltd. Lake Bluff, IL, USA). Each section of the tissue was then glued to an acrylic plate by a photolabile acrylate-based adhesive (Technovit 7210 VLC