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The effect of drilling speed on early bone healing to oral implants

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Objective. This study evaluated the effect of drilling speed on early bone healing in dog tibiae.
Study Design. Thirty-six implants (4.0-mm diameter × 10-mm length) were placed in the proximal tibiae of 6 beagles with drilling speeds of 100, 500, and 1000 rpm, and insertion torque was recorded. Bone-to-implant contact (BIC) and bone area fraction occupancy (BAFO) were evaluated.
Results. Significant increase from 1 to 3 weeks was observed for all groups for BIC, whereas no significant differences between 1 and 3 weeks were detected for the 100- and 500-rpm groups for BAFO ($P > .34$ and $P > .46$, respectively). A significant difference from 1 to 3 weeks was observed for the 1000-rpm group ($P < .03$). The 100- and 500-rpm groups presented significantly higher BAFO than the 1000-rpm group at 1 week ($P = .002$).
Conclusions. Drilling speed is one of the decisive factors for early osseointegration, and overall, drilling at 1000 rpm seemed to yield the strongest biologic responses. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:550-555)

Successful osseointegration is influenced by numerous factors, as proposed by Albrektsson et al.[1]; these include the surface topography, material properties, geometry, surgical technique, and the patient's bone status. Implant success depends on an exquisite balance of these factors, and researchers have investigated them to determine the optimal status.[2-6] Some of these factors, including topography, material properties, and geometry, are manufacturer driven, since the implant design is a predetermined factor over which the clinicians have no control. However, surgical technique is an arbitrary parameter that has the possibility to minimize surgical trauma.[7] It has been suggested that surgical experience, surgical procedures, and surgical tools influence the treatment success.[8-12]

The general consensus is that the goal of the surgical procedure is to obtain high primary stability of the implant. Primary stability is affected by implant design and insertion modalities, as well as implant micromotion and bone type.[13] Although there is diverging opinion among researchers on the exact definition of primary stability,[14-16] it can be said that less micromotion leads to the success of implant treatment. Previous studies have shown that implant micromotion of more than 150 μm leads to compromised osseointegration.[17,18] Thus, attempts to reduce micromotion naturally provide higher primary stability, which likely ensures the achievement of secondary stability.

One of the important factors that influence the implant micromotion is the drilling speed. Drilling speed can influence the accuracy of the osteotomy, and furthermore, it has an influence on heat generation in the surrounding bone.[19] It has been suggested that low drilling speed in general increases the wobbling and results in the overpreparation of the osteotomy site.[20] Furthermore, lower drilling speed has been suggested to generate more heat than high drilling speeds.[9,21,22] This may be because vertical compression force is applied during drilling for a longer time, and the overall tangential velocity and centrifugal force significantly increase.

The effect of overheating during drilling has been suggested to impair bone formation around the implant because of thermal osteonecrosis.[23] Reports indicate that overheating in the bone exceeding 47°C for 1 minute can provoke an irreversible biologic response,

Statement of Clinical Relevance

The outcomes of the current study clearly indicated that the drilling speed is one of the most important factors for successful osseointegration. Thus, understanding the biologic effects is clinically beneficial in selecting the proper drilling sequence.

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which can cause thermal injury to the bone.[24] Although necrotic bone contributes to the stability of the implant at the initial stages of bone healing,[25] this scenario results in a gradual micromotion, because the osteoclasts are activated owing to the local damage or osteocyte death.[26-28] Thus, it is suggested that an optimal drilling speed with thorough irrigation would generate less heat and necrotic supporting bone.

This study investigated the effect of different drilling speeds on the primary stability and early bone-to-implant interactions in vivo. Since the static strain in the bone during implant insertion has been reported to be one of the influential factors for the subsequent new bone formation,[29] this study investigated the accuracy of the osteotomy using different drilling speeds by means of insertion torque values. Furthermore, the biologic responses due to the different drilling speeds were evaluated histologically and histomorphometrically after 1 and 3 weeks in vivo.

MATERIALS AND METHODS

Animals and implants

This study used 36 screw-root-form endosseous titanium implants (Ti-6Al-4V alloy) of 4.0-mm diameter × 10-mm length (DT Ossean; Intra-Lock International, Inc, Boca Raton, FL, USA). Three drilling speeds were used during implant placement: 100 rpm ($n = 12$), 500 rpm ($n = 12$), and 1000 rpm ($n = 12$). All drilling procedures were conducted under abundant irrigation.

Beagle dogs, approximately 1.5 years of age and in good health, were used after the approval of the bioethics committee for animal experimentation at the National Veterinary School of Alfort, Maison-Alfort, France. The left and right tibiae of 6 dogs (3 implants per side at various drilling speeds) were used in the study.

Surgical procedure

All surgical procedures were performed under general anesthesia. Atropine sulfate (0.044 mg/kg) and xylazin chlorate (8 mg/kg) were administered intramuscularly as the preanesthetic procedure. General anesthesia was then obtained after an intramuscular injection of ketamine chlorate (15 mg/kg).

After shaving, the skin was exposed, and antiseptic cleaning with iodine solution at the surgical site and surrounding area was performed. The flap and muscle layers were reflected, and the proximal tibia was exposed. Three osteotomies were produced at least 10 mm from each other from proximal to distal, the implants were placed with a torque meter (Tohnichi, Tokyo, Japan), and insertion torque was recorded. For the current study, a trispade drill (Tri Blades; Intra-Lock International, Inc, Boca Raton, FL, USA) was used for all osteotomy procedures.

Three implants were placed along the proximal tibia in an alternated distribution, with different drilling speed groups (100 rpm, 500 rpm, and 1000 rpm) interchanged to randomize the possible effect of different implantation sites (sites 1 to 3 from proximal to distal). Therefore, the 36 implants with the various drilling speeds, remaining in vivo for either 1 or 3 weeks (right and left tibiae providing samples that remained in vivo for 1 and 3 weeks, respectively), were allocated to sites 1 to 3 in an equal distribution. This approach resulted in balanced surgical procedures that allowed the comparison of the same number of implant surfaces per time in vivo, per limb, per surgical site (1 through 3), and per animal.

Standard layered suture techniques were used for wound closure: 4-0 polyglactin 910 for internal layers (Vicryl; Ethicon, Inc, Somerville, NJ, USA) and 4-0 nylon for the skin (Ethicon, Inc). Postoperative medication included antibiotics (penicillin, 20,000 international units per kilogram) and analgesics (Ketoprophen, 1 mL per 5 kg) for a period of 48 hours postoperatively.

Euthanasia was performed by an anesthesia overdose 3 weeks after the first implantation procedure. At necropsy, the limbs were retrieved by sharp dissection, the soft tissue was removed with surgical blades, and initial clinical evaluation was performed to exclude from the study any implants with no stability.

Histologic sectioning and histomorphometry

The retrieved specimens were fixed in 10% buffered formalin solution for 24 hours, extensively washed with tap water, and gradually dehydrated in a series of ethanol solutions ranging from 70% to 100%. Thereafter, the samples were embedded in a methacrylate-based resin (Technovit 9100; Heraeus Kulzer GmbH, Wehrheim, Germany) according to the manufacturer's instructions. The blocks were then cut, with the center of the implant aimed along the long axis, with a precision diamond saw (IsoMet 2000; Buehler, Ltd, Lake Bluff, IL, USA); glued to acrylic slides with an acrylate-based resin; and allowed to set for 24 hours before grinding and polishing. The sections were then reduced to a final thickness of approximately 30 μm by means of a series of silicon carbide abrasive papers (Buehler, Ltd) in a grinding-polishing machine (MetaServ 3000; Buehler, Ltd) under water irrigation. The sections were then stained in 1% toluidine blue and referred to light microscopy for evaluation.

The evaluations of bone-to-implant contact (BIC) and bone area fraction occupancy (BAFO) between threads were performed at 100× magnification (Leica DM2500M; Leica Microsystems GmbH, Wetzlar, Germany) using the National Institutes of Health image analyzer software (ImageJ; National Institutes of Health, Bethesda, MD, USA).