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Influence of bone architecture on the primary stability of different mini-implant designs

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Introduction: Mechanical interlocking between a mini-implant (MI) and the bone substrate reflects directly on the primary stability achieved. The purposes of this study were to evaluate MI design performance in distinct bone substrates and correlate geometric characteristics with insertion site quality. **Methods:** Two types of self-drilling MIs (1.6 × 8 mm) were allocated to 2 groups according to their geometric designs: Tomas system (Dentaurum, Ispringen, Germany) and Dual-Top (Rocky Mountain Orthodontics, Denver, Colo). Forty sections (8 × 10 mm) were taken from bovine pelvic ilium and pubic bone. Geometric design characteristics were evaluated using scanning electron microscope imaging and Image-Pro Insight software (Media Cybernetics, Rockville, Md). Bone quality parameters were assessed with a microcomputed tomography system, and primary stability was evaluated by insertion torque and pull-out strength. Intergroup comparisons were performed with analysis of variance and Tukey tests, and the Pearson correlation test was carried out ($P < 0.05$). **Results:** No significant difference was observed in the comparisons of the groups (Tomas: insertion torque, 12.87 N·cm; pull-out strength, 181 N; and Dual-Top: insertion torque, 9.95 N·cm; pull-out strength, 172.5 N) in the ilium. However, the Tomas group had a marked increase in insertion torque (25.08 N·cm; $P < 0.05$) in the pubic bone. **Conclusions:** MI mechanical performance differed according to bone quality parameters, indicating that certain geometric parameters may be set depending on the insertion substrate. (Am J Orthod Dentofacial Orthop 2015;147:45-51)

Because of the challenge of controlling reciprocal tooth movement in noncompliant patients, periodontically compromised patients, and those with a reduced number of teeth undergoing orthodontic treatment,[1,2] several skeletal anchorage systems have been described in the literature over the past decades.[3-6] The wide acceptance of the orthodontic mini-implant (MI) as a temporary anchorage device can especially be attributed to minimal anatomic limitations for placement,[7] thus broadening the clinical applications.

Obtaining an efficient interface between MI and bone tissue[8] continues to be the key point to achieving higher success rates.[9] Bone quantity and quality, geometric screw designs, and insertion phase have been well described in the literature as predictors of primary stability.[8,10-13] Geometric characteristics of MIs have an impact on the interlocking surface obtained.[14] Since there is considerable variability of bone quality in the same patient,[15] further studies are still necessary to evaluate which type of MI is most suitable for the host bone site available for insertion.

Bone morphometry assessed by microcomputed tomography (micro-CT) is a reliable method to evaluate bone tissue mechanics,[16,17] and evidence from previous studies has shown that in addition to cortical bone,[18,19] trabecular bone contributes significantly to the primary stability of MIs.[20] Thus, it is possible to establish the correlation between bone architecture and MI surface properties to enhance the mechanical performance of MIs.[16] The aim of this study was to evaluate the design performance of MIs placed in distinct bone substrates to correlate geometric characteristics with insertion site quality.

MATERIAL AND METHODS

A bovine hip was chosen as the bone model. Ten bovine pelvises (*Bos taurus indicus*, Nelore lineage) were obtained from a slaughterhouse immediately after

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and Fundação de Amparo á Pesquisa do Estado do Rio de Janeiro, E-26/111.798/ 2012, Brazilian government entities, provided financial support.
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Submitted, April 2014; revised and accepted, September 2014.
0889-5406/$36.00

http://dx.doi.org/10.1016/j.ajodo.2014.09.011

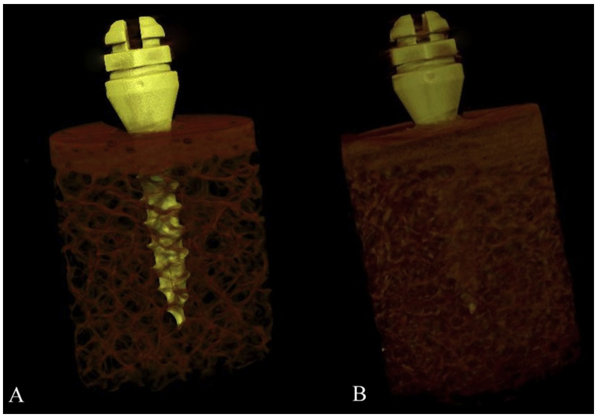

Fig 1. Micro-CT reconstructions of 2 samples from the DEN group: **A,** ilium substrate; **B,** pubic substrate.

the animals were killed. Twenty sections were taken from the iliac region, lower density bone, and another 20 from the pubic region, higher density bone.[21] Both regions had approximately 1 mm of cortical bone, measured with a caliper gauge (Dentaurum, Ispringen, Germany), and plentiful bone marrow (Fig 1). The sections were removed with a trephine bur (8 × 20 mm long; Sin Implants, São Paulo, Brazil) adapted to a hand piece with a low-speed motor (LB 100; Beltec, Araraquara, Brazil), under irrigation with abundant saline solution. The final sample (8 × 10 mm long) was immersed in saline solution and stored by freezing (−20°C).[22]

Forty self-drilling MIs (Ti-6Al-4V alloy) (1.6 × 8 mm) were allocated to groups according to their distinct design: Tomas system (Dentaurum [DEN]) and Dual-Top (Rocky Mountain Orthodontics, Denver, Colo [RMO]) (Fig 2). To study the influence of new geometric parameters on primary stability, the available MIs were selected to standardize their diameter and length. The groups (n = 10) were divided on the basis of bone region and MI group: RMO-ilium, RMO-pubic, DEN-ilium, and DEN-pubic. For sample calculation, we worked with data from a previous pilot study (α = 5%; power of study, 80%).

One examiner (A.C.C.) evaluated the MI characteristics, bone quality, and primary stability. The assessments were not blinded. It was possible to visually identify the groups by the bone and the MI characteristics. However, these variables were evaluated objectively, not influenced by the subjectivity of the evaluator.

MI photomicrographs (10, 35, 50, and 100 times magnification) were obtained by scanning electron microscope imaging (model JSM-6460LV; JEOL, Peabody,

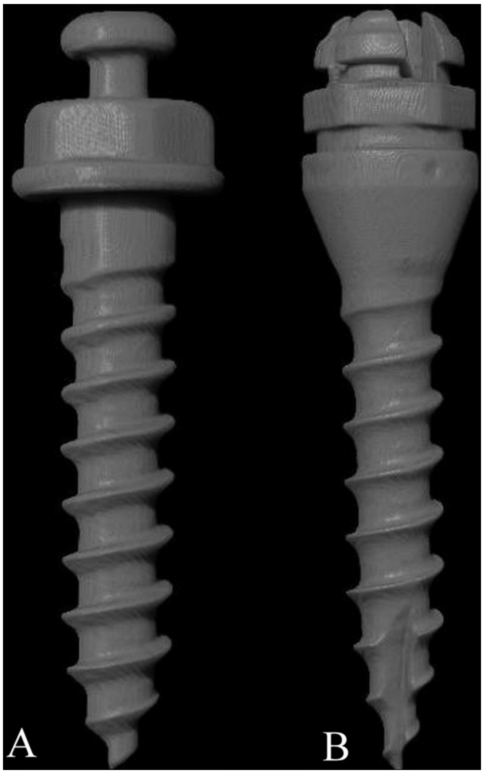

Fig 2. Micro-CT reconstructions of mini-implants: **A,** RMO group; **B,** DEN group.

Mass), and the geometric measurements were made using the Image-Pro Insight software program (version 8.0.3; Media Cybernetics, Rockville, Md) (Table 1). Thread details—angle, depth and pitch—are illustrated in Figure 3. The thread shape factor was estimated by the relationship between the pitch and depth values,[23] and the degree of conicity was determined by dividing the diameter of 2 shank sections by the pitch. The highest degree of conicity value was considered for each MI group.

Micro-CT was used to obtain an accurate bone morphometric assessment. Images of the samples were acquired in the micro-CT system (model 1173; Bruker, Kontich, Belgium) with resolution of 14.8 μm, 1-mm thick aluminum filter, 80 kV, 90 μA, and exposure of 800 ms. The samples were kept in 2-mL Eppendorf tubes containing saline solution with the bolt head facing upward. Each 3-dimensional image data set consisted of approximately 800 micro-CT slice images (1.12 × 1.12 pixels) that were reconstructed and evaluated using the NRecon (InstaRecon, Champaign, Ill) and CT-Analyzer software programs (Bruker), respectively. Six bone voxels adjacent to the center (88.8 μm) were excluded from the volume of interest (a cylinder with a