

## Is miniscrew primary stability influenced by bone density?

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**Abstract:** Primary stability is absence of mobility in the bone bed after mini-implant placement and depends on bone quality among other factors. Bone quality is a subjective term frequently considered as bone density. The aim of this preliminary study was to evaluate bone density in two bovine pelvic regions and verify the primary stability of miniscrews inserted into them. Forty bone blocks were extracted from bovine pelvic bones, 20 from iliac and 20 from pubic bone, all of them containing cortical bone about 1 mm thick. Half of the sections extracted from each bone were designated for histological evaluation of bone density (trabecular bone area - TBA) and the other half for bone mineral density (BMD) evaluation by means of central dual-energy X-ray absorptiometry (DEXA). Then, twenty self-drilling miniscrews (INP®, São Paulo, Brazil) 1.4 mm in diameter and 6 mm long were inserted into the bone blocks used for BMD evaluation. Peak implant insertion torque (IT) and pull-out strength (PS) were used for primary stability evaluation. It was found that iliac and pubic bones present different bone densities, iliac bone being less dense considering BMD and TBA values ( $P > 0.05$ ). However, the miniscrew primary stability was not different when varying the bone type ( $P < 0.05$ ). IT and PS were not influenced by these differences in bone density when cortical thickness was about 1 mm thick.

**Descriptors:** Bone and Bones; Bone Density; Orthodontic Anchorage Procedures.

### Introduction

Primary stability is absence of mobility in the bone bed after implant or mini-implant placement.<sup>1,2</sup> It is achieved by mechanical contact between the miniscrew surface and bone<sup>3</sup> and depends on the characteristics of devices<sup>4,5</sup>, insertion technique<sup>4</sup> and bone quality and quantity of the receptor site.<sup>4,6-8</sup>

The primary stability plays an important role in the successful secondary stability of miniscrews, since lack of immediate stability can lead to progressive mobility of the device and its subsequent loss.<sup>9</sup> In clinical use, the initial stability of miniscrews is also considered essential, because of immediate or early load applied on them in many patients.<sup>10</sup> It has been suggested that if initial mechanical retention of the mini-implant is not observed, it should be replaced by a thicker device, or its insertion site should be changed.<sup>11</sup> Primary stability has traditionally been assessed by the practitioner through manual verification.<sup>12</sup> Several other less subjec-

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tive methods are described in the literature: histological (BIC - bone to implant contact), which assesses the percentage of bone to implant contact; mechanical, which assesses insertion and removal torque or pullout strength of mini-implants, and the percussion method (Periotest value). However, there is still no gold standard to assess the primary stability of miniscrews.<sup>13</sup>

The term “bone quality” is not clearly defined in the literature. This includes physiological and structural aspects and degree of bone tissue mineralization.<sup>14</sup> Aspects such as bone metabolism, cell turnover, maturation, intracellular matrix and vascularity have also been emphasized.<sup>1</sup> Nevertheless, the role of each of these aspects is not completely understood.<sup>14</sup> In Implant dentistry, the most accepted classification of bone quality has been the one proposed by Lekholm and Zarb.<sup>15</sup> This was based on the amount of cortical and trabecular bone shown in preoperative radiographs. This classification, however, depends on the operator’s subjectivity during radiographic evaluation.

A less subjective method for evaluating cortical and trabecular bone quality is to verify bone mineral density (BMD).<sup>14</sup> Bone densitometry is taken as the gold standard for quantifying BMD in Endocrinolo-

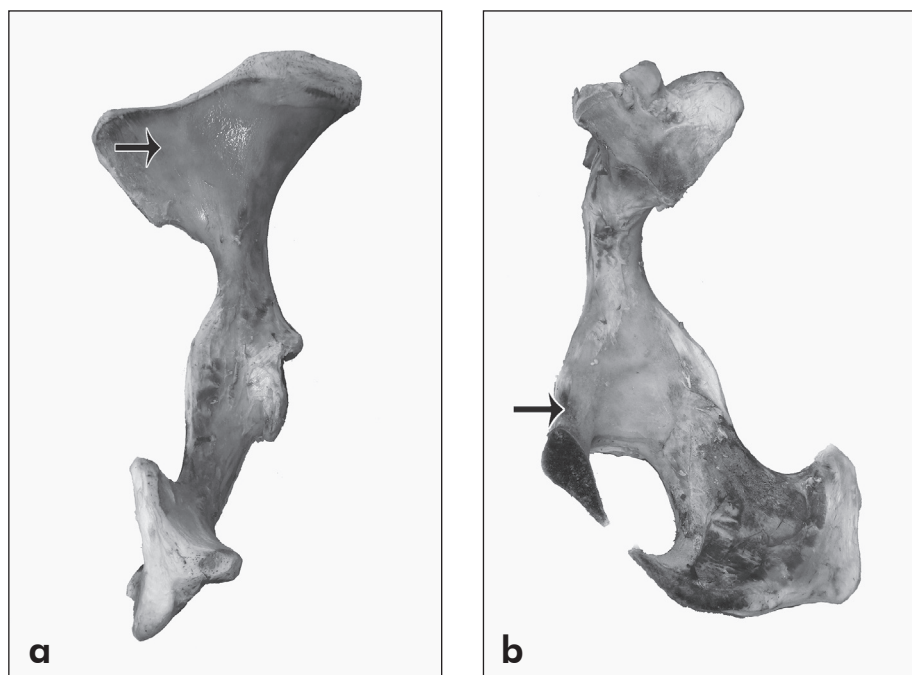
gy and Traumatology.<sup>16</sup> The bone mineral content of tissue is measured and divided by the area of tissue to obtain bone mineral density. Another parameter of bone quality evaluated in implant dentistry is trabecular bone density. For this measurement, however, the percentage of trabecular bone area in the total biopsy area is calculated. The trabecular bone area (TBA) instead of mineral content is evaluated. For TBA analysis, histological and morphometrical methods are considered the gold standard.<sup>1</sup>

Considering the above, the aim of this study was to evaluate the primary stability of miniscrews inserted in two bovine pelvic regions with different densities, to verify the influence of bone density on stability.

## Methodology

The sample comprised 40 bone sections extracted from bovine pelvis (*Bos taurus*), Angus lineage. Ten pelvic bones were obtained from a Slaughterhouse (registered with ANVISA – the Brazilian Health Surveillance Agency) immediately after slaughter. From each bone, two small bone sections were taken from the gluteal wing of the iliac and from the pubic bone (Figure 1). Tissue sections were removed by means of a trephine bur (8 mm in diam-

**Figure 1** - Macroscopic view of the right hemi pelvis. **(a)** caudal view: the arrow indicates the gluteal wing of the iliac bone. **(b)** medial view: the arrow indicates the caudal portion of the pubic bone.



eter × 20 mm long, Sin Implantes, São Paulo, Brazil) adapted to a low speed motor (Beltec LB100, Araquara, Brazil) under irrigation. The bone sections were taken from a region in which cortical bone was about 1 mm thick (measured with an orthodontic caliper, Odin, Ortho-pli, Philadelphia, USA). One of the two bone sections taken from each region was used to measure bone mineral density and evaluate primary stability. These samples were immersed in sterile physiological solution and stored by freezing (−20 °C) until the tests were performed. The other section removed from each bone was used for histomorphometric analysis. These samples were immersed in 10% buffered formalin solution for 2 days for fixation.

### Bone mineral density evaluation (BMD)

The bone mineral content of specimens was measured and divided into areas to obtain bone mineral density by means of central dual-energy X-ray absorptiometry (DEXA) (GE/Lunar Prodigy, Madison, USA), calibrated for small animals. To perform the exam, the bone blocks were thawed at room temperature and were put into plastic boxes (6 × 11 × 4 cm) containing raw rice to simulate soft tissue during irradiation. After this the samples were irradiated by DEXA for 30 seconds.<sup>17</sup>

### Histomorphometric evaluation

After being immersed in 10% buffered formalin solution for 2 days, the samples were decalcified in Morse solution<sup>18</sup> (equal parts of 50% formic acid and 20% sodium citrate - Vetec Química Fina Ltda., Rio de Janeiro, Brazil) by immersion for 7 days and then embedded in paraffin. Longitudinal sections were cut into 5- $\mu$ m slices and stained with picosirius for histologic evaluation. Histomorphometric analysis of bone samples was performed using Image J software (National Institute of Mental Health, Bethesda, USA). Digitized photomicrographs (microscope Nikon Eclipse E600, magnification ×40, camera DS-U2, Nikon Corporation, Tokyo, Japan) were taken and analyzed by the same examiner (ICC = 0.971). The histomorphometric evaluation result was given as a percentage of trabecular bone area (TBA).

### Primary stability evaluation

Primary stability was evaluated by measuring insertion torque (IT) and pull-out strength (PS). Twenty miniscrews (INP®, São Paulo, Brazil) 1.4 mm in diameter and 6 mm long were inserted into the bone blocks used for BMD evaluation. This was done with the use of a manual placement key connected to a digital torque meter (Lutron TQ-8800, Taipei, Taiwan), to allow the measurement of peak implant placement torque. The values were recorded in Newton centimeter (Ncm). After this, the pull-out test, which consists of extracting the miniscrew from bone at a constant velocity, was performed to evaluate the maximum force required to remove it.<sup>19</sup> The mechanical test was performed in a universal test machine (Emic DL 2000, São José dos Pinhais, Brazil), using a 500 kgf load cell at a crosshead speed of 0.05 mm per second<sup>19</sup> to remove the miniscrew. The maximum pull-out strength was recorded.

### Statistical analysis

The data were evaluated using the Statistical Package for Social Sciences (version 17, SPSS Inc., Chicago, USA). The values obtained were tabulated and submitted to descriptive analysis. The normality and homogeneity of variables were verified by Shapiro-Wilk and Levene's tests. Intergroup comparisons of mean values were performed by the paired T-test at a level of significance of 5%.

## Results

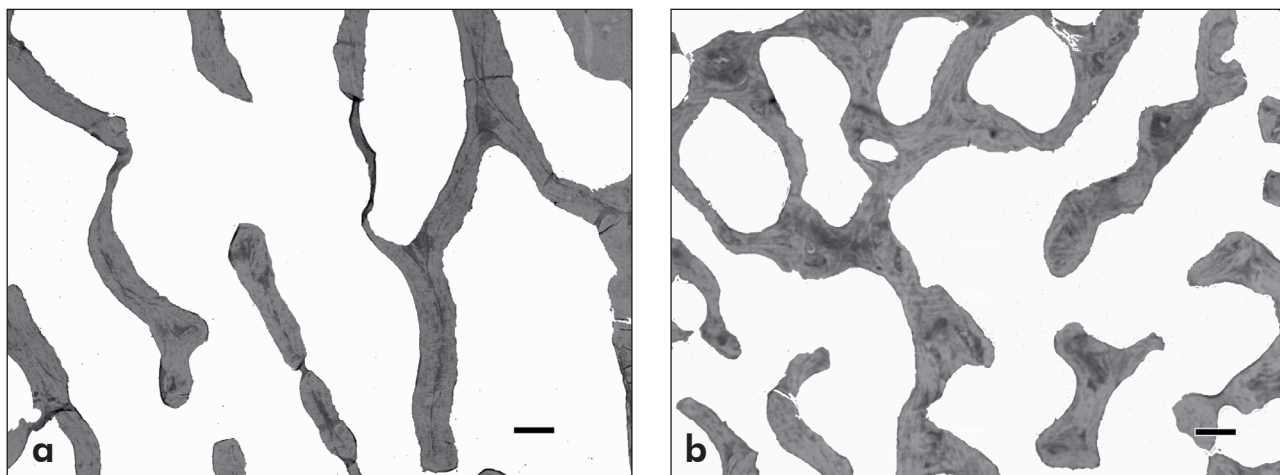
Under light microscopy, the histological sections revealed the presence of trabecular bone with osteocytes and marrow spaces filled with fat marrow. The marrow spaces were larger in Iliac bone. Descriptive statistics and the paired T-test results are shown in Table 1.

Statistical difference was observed for the variables that evaluated bone quality: BMD – P = 0.000; TBA – P = 0.002. The difference in trabecular bone density between the iliac and pubic bones is shown in Figure 2. The variables that evaluated primary stability (IT and PS) showed no statistical difference (P = 0.071 and P = 0.387, respectively).

**Table 1** - Descriptive analysis and paired T-test comparing the four variables for iliac and pubic bones.

	Iliac (mean and SD)	Pubic (mean and SD)	paired T-test
BMD g/cm <sup>2</sup>	0.13 (0.01)	0.16 (0.00)	P = 0.000*
Trabecular bone density (%)	24.23 (6.12)	39.01 (7.95)	P = 0.002*
IT (Ncm)	7.13 (0.75)	6.23 (0.20)	P = 0.071
PS (N)	203.33 (91.11)	164.33 (23.07)	P = 0.387

\* Indicates statistical significant difference at  $\alpha = 0.05\%$



**Figure 2** - Micrograph of iliac (a) and pubic (b) bones (picrosirius, 40x, bars = 100 µm). Note that the marrow spaces are larger in iliac bone (a).

## Discussion

Pelvic bone has previously been used in studies with miniscrews.<sup>4,20,21,22</sup> During exploration of this bone, it was observed that some characteristics such as color, texture and drill resistance differed in its various regions. Pubic bone was darker and more resistant when compared with iliac bone. Therefore, these two regions of the pelvic bone were chosen for this study. The BMD results showed that they are less dense than human jaw bones, as previously related in the literature by Devlin *et al.*,<sup>23</sup> indicating the following values: maxilla anterior region = 0.55 g/cm<sup>2</sup>; maxilla posterior region = 0.31 g/cm<sup>2</sup>; mandible = 1.11 g/cm<sup>2</sup>; and by Choel *et al.*,<sup>24</sup> indicating values for dentate mandible = 0.604 g/cm<sup>2</sup>; and edentulous mandible = 0.521 g/cm<sup>2</sup>. However, the two cited studies presented a large variation in values for mandibular BMD. Trabecular bone density evaluation, however, showed that the TBA value for pubic bone was similar to the results previously described by Aksoy *et al.*<sup>25</sup> for maxilla (= 38.20 ± 9.65)

and for mandible (= 44.08 ± 14.97). The results of this study showed that the iliac and the pubic bones (of which the pelvis is composed) present different bone qualities: bone mineral density and trabecular bone density. These characteristics, however, had no influence on the primary stability of mini-implants inserted in bone when the cortical was 1 mm thick.

Mean values for IT ranged from 6.23 to 7.13 Ncm, representing adequate primary stability according to Motoyoshi *et al.*,<sup>26</sup> who stated that these values should range from 5 to 10 Ncm.

Pull-out strength values ranged from 164.33 to 203.33 N, being within the range found by Huja *et al.*<sup>19</sup> in a study with dog jaws: 134.5 N, for anterior mandible, and 388.3 N for posterior mandible. Nevertheless, no landmark for adequate pull-out strength value was found in the literature.

A previous study evaluated the influence of BMD on the primary stability of miniscrews and, despite methodological differences, found a similar result.<sup>27</sup> No correlation was found between BMD, verified

by cone beam computed tomography, and miniscrew stability, assessed by placement torque. The authors also investigated the influence of cortical bone and found that cortical thickness and cortical BMD were positively correlated with miniscrew stability.<sup>27</sup> No studies evaluating the influence of TBA on miniscrew stability were found.

Two hypotheses were formulated to explain the results of the present study. The first is that the presence of a cortical thickness of 1 mm in all of the specimens had an important influence on miniscrew stability, masking the influence of bone mineral density and trabecular density. Cortical thickness has been related to primary stability of miniscrews and implants.<sup>5,12,28,29,30</sup> However, there is a lack of studies isolating these two factors: bone density and cortical thickness. The second hypothesis is that the difference in bone quality verified statistically may not be clinically relevant. A bigger difference between BMD and TBA values in bones could perhaps reflect differences in mini-implant stability.

Despite the limitations of this *in vitro* study, it can be inferred that, in clinical practice, a cortical thickness of 1 mm is sufficient to guarantee the primary stability of miniscrews, as previously sup-

posed by Motoyoshi *et al.*,<sup>30</sup> even when there are variations in BMD and TBA values.

Further research is suggested isolating the cortical effect and increasing the difference in density between different types of bone.

## Conclusions

- Iliac and pubic bones present different BMD and TBA values, the iliac being less dense when considering the two parameters;
- Miniscrew primary stability was not influenced by these differences in bone density.

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