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SCIENCE DIRECT®
Chirurgie de la main 25 (2006) 77–80
CHIRURGIE DE LA main
http://france.elsevier.com/direct/CHIMAI/

Article original

Bone density comparison of selected carpal and tarsal bones: validation for their use in compression fracture fixation studies of scaphoid screws

Comparaison des densités osseuses de certains os carpiens et tarsiens: validation de leur utilisation dans les études de techniques d'ostéosynthèse des fractures du scaphoïde par vissage compressif

J.P. Brutus *, J.S. Rajkumar, E. Rust, B.J. Harley, A.K. Palmer, F.W. Werner

Department of Orthopedic Surgery, State University of New York, Upstate Medical University, Institute for Human Performance, 505 Irving Avenue, Syracuse, NY 13210, USA

Abstract

Introduction. – To determine if trabecular, total and cortical bone densities of the capitate, navicular, cuboid, and first cuneiform were equivalent to those of the scaphoid, such that these bones could be used in place of the scaphoid in evaluating new headless scaphoid compression screws.

Methods. – Fifty scaphoids, capitates, naviculars, cuboids, and first cuneiforms were harvested from fresh frozen cadavers. The trabecular, total and cortical bone densities were measured using pQCT technology and statistically compared.

Results. – A paired *t* comparison between paired scaphoids and capitates showed no difference between the trabecular bone densities. However, their total bone and cortical densities were found to be different. An independent measures ANOVA comparison of the five bones, showed no significant difference in mean trabecular density between the capitates, naviculars and first cuneiforms when compared to the scaphoids. However, the mean total and cortical densities of the first cuneiforms were less than the scaphoids and the mean trabecular, total and cortical bone densities of the cuboids were all less than the scaphoids.

Discussion. – Compression fracture fixation studies of headless compression screws could be conducted using the capitate, navicular, and first cuneiform as models of the scaphoid when the supply of scaphoids is limited.

Résumé

Introduction. – L'objectif de ce travail fut de déterminer si les densités osseuses trabéculaire, totale et corticale du grand os, du naviculaire tarsien, du cuboïde et du premier cunéiforme se rapprochent de celles du scaphoïde de manière à ce que ces os puissent être utilisés dans les études de laboratoire testant les nouvelles vis à compression destinées à la synthèse des fractures du scaphoïde.

Méthodes. – Cinquante scaphoïdes, grands os, cuboïdes, naviculaires et premiers cunéiformes furent prélevés sur cadavres frais congelés. Les densités osseuses trabéculaire, totale et corticale des spécimens furent mesurées par tomographie computérisée quantitative périphérique et une étude statistique effectuée.

Résultats. – La comparaison entre paires de scaphoïdes et de grands os n'a pas montré de différence de densité de l'os trabéculaire, mais a révélé des différences pour les densités osseuses totale et corticale. Une comparaison de mesures indépendantes ANOVA entre les cinq os n'a pas

* Corresponding author. Present address: 47, rue du Cardinal Lavigerie, 1040 Brussels, Belgium.
E-mail address: jpbrutus@hotmail.com (J.P. Brutus).

1297-3203/$ - see front matter © 2006 Published by Elsevier SAS.
doi:10.1016/j.main.2006.04.002

révélé de différence significative de densité trabéculaire moyenne entre le grand os, le naviculaire tarsien, le premier cunéiforme et le scaphoïde. Cependant, nos résultats nous apprennent que les densités moyenne, totale et corticale dans le groupe de premiers cunéiformes furent inférieures à celles des scaphoïdes, et que les densités trabéculaires moyenne, totale et corticale des cuboïdes furent toutes inférieures à celles des scaphoïdes.

Discussion. – Le grand os, le naviculaire tarsien, et le premier cunéiforme peuvent être utilisés comme modèles de scaphoïdes pour les études de laboratoire portant sur les nouvelles vis d'ostéosynthèse à compression lorsque la disponibilité des spécimens de scaphoïdes frais est limitée.

Keywords: pQCT; Scaphoid; Tarsal bones; Bone densitometry

Mots clés : pQCT ; Scaphoide ; Os tarsiens ; Densitométrie osseuse

1. Introduction

The scaphoid is the most frequently fractured carpal bone. Internal fixation of the fractured scaphoid is used to promote union between bone fragments and to decrease the duration of wrist joint immobilization. Many factors are felt to influence the outcome of a scaphoid fracture (type and location of fracture, vascularity, smoking, delay before treatment) and the quality of the fixation may be the only factor which the surgeon has control of. When selecting the appropriate hardware, adequate compression of the fracture site may be one of the most important parameters because it promotes healing, provides stability and resists rotation of the fragments [1–3].

Assuming that increasing compression is beneficial and will lower failure rates, it is necessary to test internal fixation devices to determine which ones provide the most compression between fragments. Both cadaveric material and synthetic models have been used to test compression, but cadaveric bone is more likely to predict in vivo behavior of the screws. Unfortunately, scaphoids are often in short supply in laboratory settings and some authors have substituted cylinders of trabecular bone harvested from the femur or synthetic material [3–6]. Our hypothesis was that other carpal or tarsal bones could be used as models for the scaphoid bone if it could be demonstrated that these bones had similar geometry and bone density patterns.

The purpose of this study was to determine if the capitate, navicular, cuboid, and/or the first cuneiform can be used as alternative models of the scaphoid to perform in vitro testing of various headless compression screws. The trabecular, cortical and total bones densities of these alternative bones were compared.

Trabecular bone density is felt to be the most important parameter tested because the carpal and tarsal bones are composed primarily of trabecular bone, and it is in this bone that the scaphoid screws find purchase.

2. Materials and methods

Ten scaphoids, 10 capitates, 10 naviculars, 10 cuboids, and 10 first cuneiforms were harvested from fresh frozen cadavers and all soft tissues removed (13 females, eight males; mean age of donors: 70.7 years, median 73). The bones were thawed for scanning on a Norland Stratec XCT 2000 peripheral quantitative computer tomography (pQCT) scanner (Pforzheim, Germany). Since the pQCT scanner is designed to scan the intact human forearm in a proximal to distal direction, a method was devised by which each type of bone could be scanned in a repeatable orientation and in a proximal to distal direction.

Five plastic specimen containers were used, one for each of the five different bones. A cylindrical piece of hard, porous foam was inserted into the container so that it filled the bottom third to half of the container's volume. A depression was cut into the foam so that each bone type fit neatly into the foam and was held securely in the proper orientation inside the container. The container was then filled with de-ionized water and placed horizontally on the scanning bed such that the long axis of the bone was parallel to the scanning bed.

For the scaphoid, a surgical marker was used to draw a line at the narrowest region of the bone, where waist fractures commonly occur. The container was positioned so that the volar surface of the bone was oriented towards the floor and so that the proximal end would be scanned first. The capitate, cuboid, and first cuneiform were oriented similarly with the volar or plantar surface facing downwards and the "fracture site" was placed at the midpoint of the long axis. Due to its altered geometry, the navicular was scanned differently. If a navicular is to be used for a compression screw model, the screw would probably be inserted parallel to the long axis of the bone from medial to lateral. The navicular was positioned such that the plantar surface faced downwards during the scan but the medial surface of the bone was placed so that it was scanned first.

The length of each bone, except the scaphoid, was measured on the long axis and this was used by the computer to determine the midpoint of the bone. Each bone was scanned perpendicular to its long axis. The location of the scan slice was at the midpoint of the long axis of each bone except for the scaphoid, where the slice location was at the narrowest region of the bone. Each scan slice was an average of 2.2 mm thick. The voxel size used was 0.2 mm. After the scan, each slice was analyzed to calculate the total density of the bone slice, the density of just the trabecular bone, and the density of the cortical shell plus the subcortical bone (here called the cortical bone density). For this analysis the inner threshold used was 650 mg/cm^3, the threshold was 169 mg/cm^3, and the concentric peel was by 5%. The inner threshold is used to delineate between trabecular and cortical–subcortical bone. These thresh-