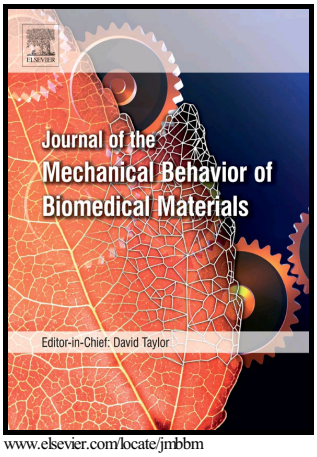
Author's Accepted Manuscript



www.elsevier.com/locate/jmbbm

Influence of cement compressive strength and porosity on augmentation performance in a model of orthopedic screw pull-out

Michael Pujari-Palmer, Celine Robo, Cecilia Persson, Philip Procter, Håkan Engqvist

PII: S1751-6161(17)30444-7
DOI: https://doi.org/10.1016/j.jmbbm.2017.10.016
Reference: JMBBM2536

To appear in: *Journal of the Mechanical Behavior of Biomedical Materials*

Received date: 1 August 2017
Revised date: 9 October 2017
Accepted date: 10 October 2017

Cite this article as: Michael Pujari-Palmer, Celine Robo, Cecilia Persson, Philip Procter and Håkan Engqvist, Influence of cement compressive strength and porosity on augmentation performance in a model of orthopedic screw pull-out, *Journal of the Mechanical Behavior of Biomedical Materials,* https://doi.org/10.1016/j.jmbbm.2017.10.016

Influence of cement compressive strength and porosity on augmentation performance in a model of orthopedic screw pull-out

Michael Pujari-Palmer, Celine Robo, Cecilia Persson, Philip Procter, Håkan Engqvist
Box 534, SE-751 21 Uppsala, Sweden
Materials in Medicine, Div. of Applied Materials Science, Dept. of Engineering Sciences
Uppsala University, Uppsala Sweden

*hakan.engqvist@angstrom.uu.se

Abstract

Disease and injuries that affect the skeletal system may require surgical intervention and internal fixation, i.e. orthopedic plate and screw insertion, to stabilize the injury and facilitate tissue repair. If the surrounding bone quality is poor the screws may migrate, or the bone may fail, resulting in fixation failure. While numerous studies have shown that cement augmentation of the interface between bone and implant can increase screw pull-out force, the physical properties of cement that influence pull-out force have not been investigated. The present study sought to determine how the physical properties of high strength calcium phosphate cements (hsCPCs, specifically dicalcium phosphate) affected the corresponding orthopedic screw pull-out force in urethane foam models of "healthy" and "osteoporotic" synthetic bone (Sawbones). In the simplest model, where only the bond strength between screw thread and cement (without Sawbone) was tested, the correlation between pull-out force and cement compressive strength (R^2 = 0.79) was weaker than correlation with total cement porosity (R^2 = 0.89). In open pore Sawbone that mimics "healthy" cancellous bone density the stronger cements produced higher pull-out force (50-60% increase). High strength, low porosity cements also produced higher pull-out forces (50-190% increase) in "healthy" Sawbones with cortical fixation if the failure strength of the cortical material was similar to, or greater than (a metal shell), actual cortical bone. This result is of particular clinical relevance where fixation with a metal plate implant is indicated, as the nearby metal can simulate a thicker cortical shell, thereby increasing the pull-out force of screws augmented with stronger cements. The improvement in pull-out force was apparent even at low augmentation volumes of 0.5 ml (50% increase), which suggest that in clinical situations where augmentation volume is limited the stronger, lower porosity calcium phosphate cement (CPC) may still produce a significant improvement in screw pull-out force. When the correlation strength of all the tested models were compared both cement porosity and compressive strength accurately predicted pull-out force (R^2=1.00, R^2=0.808), though prediction accuracy depended upon the strength of the material surrounding the Sawbone. The correlations strength was low for bone with no, or weak, cortical fixation (R^2=0.56, 0.36). Higher strength and lower porosity CPCs also produced greater pull-out force (1-1.5 kN) than commercial CPC (0.2-0.5kN), but lower pull-out force than PMMA (2-3 kN). The results of this study suggest that the likelihood of screw fixation failure may be reduced by selecting calcium phosphate cements with lower porosity and higher compressive strength, in patients with healthy bone mineral density and/or sufficient cortical thickness. This is of particular clinical relevance when fixation with metal plates is indicated, or where the augmentation volume is limited.

Key words – screw pull-out, orthopedic screw augmentation, calcium phosphate cement, bioceramic, bone biomechanics, Sawbones, cortical fixation.

1. Introduction

In many situations where operative procedures are indicated, implants such as intramedullary devices, screws, and plates are used to stabilize injured bone, and enable earlier load bearing, to facilitate healing[1]. Orthopedic screws are the most common fixation strategy for connecting implants, e.g. plates, rods, etc., during anatomic reduction and internal fixation procedures[1]. If the surrounding bone is of poor quality, i.e., osteopenic or osteoporotic bone, it may be damaged under loading, or the screw may migrate, resulting in destruction of the surrounding tissues and loosening of the screw. The incidence of loss of fixation, including loss due to screw migration and pull-out, is estimated to be higher than 10%[2-5]. Screw pull-out testing measures the total energy and maximum pull-out force of an inserted orthopedic screw[6]. Though many parameters contribute to the final anchoring strength of a screw (thread diameter, depth, pitch, etc,), the quality of surrounding bone is a primary limiting factor[7-10].

Cements can augment screw fixation by spreading into the porous regions of cancellous bone and physically bond to both screw, implant and bone[7]. The majority of studies, in synthetic bone-like models and in actual tissue, report that cement augmentation produces a clear benefit in pull-out force[11-13]. Poly-methyl