

# Mechanical Analysis of Percutaneous Sacroplasty using CT Image based Finite Element Models

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## INTRODUCTION

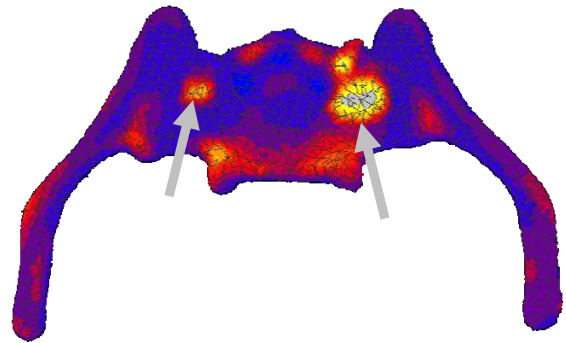
Vertebroplasty is a widely used procedure for treatment of vertebral compression fractures. It consists of the injection of polymethylmethacrylate (PMMA) bone cement into the cancellous core of the vertebral body. Recently a similar technique, called sacroplasty, has been used in the treatment of sacral insufficiency fractures. Early clinical results, such as presented by Pommersheim et al (2003), indicate sacroplasty is effective in relieving pain and improving daily function. We present here a finite element analysis that examines the mechanical effects of sacroplasty: namely the stiffening effects on the whole sacrum, as well as the redistribution of strain energy in and around the cemented area.

## METHODS

Finite element models were constructed based on Computed Tomography (CT) images from a cadaver in a bilaterally sacroplasty was performed. The model geometry, which included the sacrum and the upper portions of the ilia, was defined from the CT image. MSC.Patran (MSC Software, Santa Ana, CA) was used to create finite element meshes based on the defined bone geometry (Anderson and Cotton, 2006).

In addition to geometry, the CT image was used to create non-homogeneous material properties for the bone in the finite element model. This was done using Bonemat, developed by Taddei et al (2004), and by

estimating reasonable values for mineral density and bone modulus for the sacrum. Cement areas were brighter on the CT image than bone and were assigned a value of 2.5 GPa. Figure 1 shows the resulting modulus variation in the model, where the cement can be clearly seen.



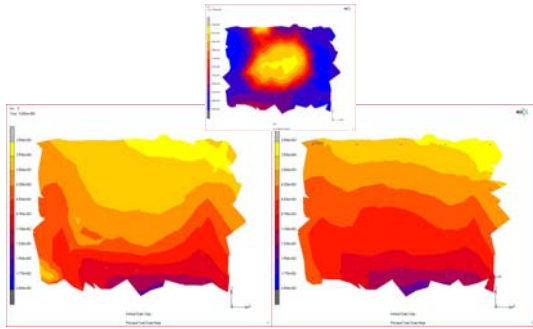
**Figure 1:** Modulus variation in a coronal section of the sacral model. The arrows indicate the bilateral locations of the cement.

To examine the sacroplasty effect, the above model was compared to the same model except the cemented elements were replaced by elements assigned representative values of cancellous bone.

## RESULTS AND DISCUSSION

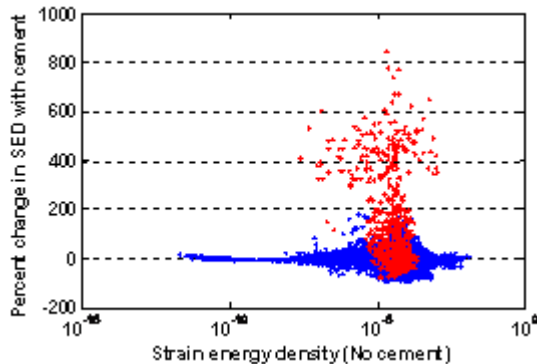
Principal strain magnitudes and directions were compared in both the cemented and uncemented models. In both, compressive strains were the largest, although tensile and shear strains were also significant. In the locations of the cement, strains were reduced (Figure 2). This local effect was sizeable, reducing strains an average of 30%, some by as much as 70%. While a few

element strains increased, highly strained elements uniformly saw their strains drop.



**Figure 2.** Comparison of right cemented area with cement (left) and no cement cases (right). Major principle strains ranging from 250 to  $-2000 \mu\epsilon$ . Inset is the modulus for the cement case, showing cement location.

Despite this local effect, under identical loads the cemented case deflected roughly 2% less. Therefore, the cemented case has slightly less energy to cause damage or pain. Figure 3 shows how this strain energy is redistributed. The stiffer cement elements absorb more energy. However, the volume of cemented elements is not great. Overall, the strain energy in the putative cemented areas increases from 0.73 to 1.84% of the total strain energy by the addition of cement.



**Figure 3.** The uncemented strain energy in each element changes with sacroplasty. In red are cemented elements, while uncemented elements are blue.

In contrast, examinations of vertebroplasty have shown that it can significantly increase

vertebral body strength and stiffness. The increase is greater for larger amounts of cement. Liebschner (2001) predicted with finite element models that cement could increase vertebral body stiffness by almost 50% over the intact stiffness. Heini (2001) found stiffness increases of 174% in osteoporotic vertebrae. In these cases, the volume of cement injected was 25–50% of the vertebral body volume. In this study, the cement volume was estimated at about 1% of the sacral volume. To obtain percent fills comparable to vertebroplasty would require significantly more cement, as the sacrum is larger than a vertebral body. If the sacrum is limited to small percent fills, the effects of sacroplasty will be primarily limited to the local areas around the cement, as was seen in this model.

## SUMMARY

Sacroplasty acts to reduce the strains in the sacrum, especially in the regions where the cement is present. The overall model was only stiffened slightly.

## ACKNOWLEDGEMENTS

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