PATIENT-SPECIFIC BONE MODELING CAN BETTER PREDICT BIOMECHANICAL OUTCOMES OF SACRAL FRACTURE FIXATIONS

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Introduction

The sacrum is a biomechanical keystone as it transmits the load from the upper body to the lower extremities. High-energy traumas, such as car accidents or falls from height, can cause sacral fractures and an unstable pelvic ring [1]. Due to the more frequent use of pelvic CT scans, sacral fractures are more often recognized and treated surgically, although there is still controversy regarding the optimal management [2]. Previous finite element (FE) analyses were performed to assess fixation techniques used for sacral fracture treatment. However, all these investigations assumed identical bone quality at the S1 and S2 levels and employed averaged bone material properties, thus ignoring the biomechanical effect of local bone qualities [3,4]. Therefore, the current study aimed to evaluate the effect of the locally defined patient-specific bone quality by applying two different sets of bone material properties in six different fixation techniques used for treating Denis Type II unilateral sacral fractures.

Methods

Two FE models of the intact pelvis were constructed; the literature-based model (LBM) was developed with homogenous bone material properties taken from the literature, while the patient-specific model (PSM) was created with heterogenous bone material properties based on the quantitative CT scans. Unilateral transforaminal sacral fracture was modelled to assess six different fixation techniques: iliosacral screw (ISS) at S1 (ISS1), ISS at S2 (ISS2), ISS at S1 and S2 (ISS12), transverse iliosacral screw (TISS) at S1 (TISS1), TISS at S2 (TISS2), and TISS at S1 and S2 (TISS12) (Figure 1a-f). A 600 N vertical load with both acetabula fixed was applied to simulate a double leg stance. Vertical stiffness (VS) normalized with the intact condition, relative interfragmentary displacement (RID), and the von Mises stress values on the fracture interface were analyzed.

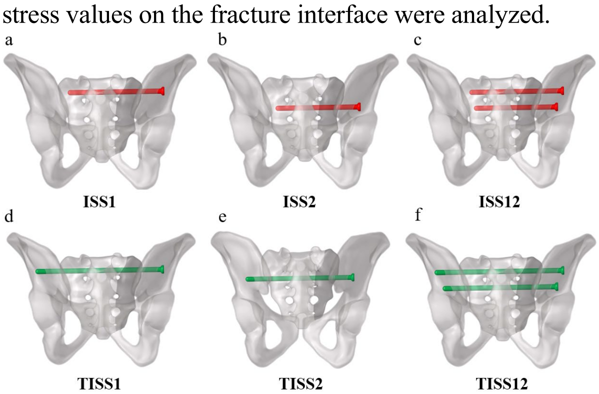

Figure 1: The investigated fixation configurations: (a) ISS1, (b) ISS2, (c) ISS12, (d) TISS1, (e) TISS2, (f) TISS12.

Results

The lowest and highest normalized VS was given by ISS1 and TISS12 techniques for LBM and PSM, 137% and 149%, and 375% and 472%, respectively. The maximum RID values were between 0.10 mm and 0.47 mm for all fixation techniques in both models. The von Mises stress results on the fracture interface show a substantial difference between the two bone modeling techniques, as PSM gave significantly lower stress values for all fixation techniques than LBM. Regarding the maximum stress values, the LBM gave higher values by 255.1, 20.3, 156.4, 286.9, 41.1 and 171.1 % compared to PSM. The boxplot figure including nodes that fell within the largest 1% of the stress values on the fracture surface are shown in Figure 2.

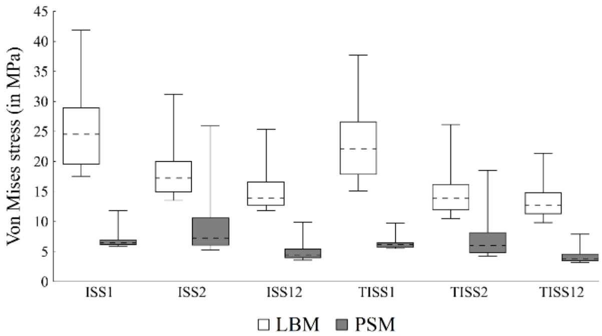

Figure 2: Boxplot figure with nodes from LBM and PSM that fell within the largest 1% of the von Mises stress values on the fracture surface.

Discussion

Based on our results, all techniques can provide clinically sufficient stability. TISS12 was superior to all other fixations from a biomechanical point of view. Patient-specific bone modelling revealed that sacral fracture fixations should prioritize the S1 level over the S2, although long-term clinical trials are recommended to confirm the findings of the study.

References

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