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PATIENT- SPECIFIC FINITE ELEMENT ANALYSIS OF LONG BONES – APPLICATIONS IN CLINICAL PRACTICE

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Finite element analyses in orthopedic biomechanics are mainly applied on generic or average bones, used to draw general conclusions. For non trivial clinical cases, fracture risk assessment and pre-operative planning, a patient- specific model is necessary [1]. Patient-specific simulations aimed to be used in clinical orthopaedic practice should demonstrate that they are verified, validated by experiments and obtained automatically in a short time-scale. Such V&V simulations, based on quantitative CT (qCT) scans, were developed using high-order finite element methods (p-FEMs), demonstrating an unprecedented prediction capability [2, 3]. QCT can be used to (noninvasively) extract bone geometry and determine its material properties; these being the two key ingredients for FE models of bones. We describe the methods used for creating patient specific p-FE models and the large set of in-vitro experiments used to assess their validity.
V&V methodology was applied to 31 fresh frozen human femurs and 7 first and second metatarsals. In 12 femurs a double-blinded process was followed to avoid any bias [3]. Six pairs of fresh frozen femurs with variety metastatic tumors were also included in the V&V study. For all specimens numerical and experimental results were compared and the deviation was calculated for the measured parameters: both strains and displacements. The corroboration between FEA and experiment is determined by regression analysis for all individual measurements. Overall, the FE analyses show excellent predictability of strains and displacements with regression coefficients (R^2)>0.95 and slopes of the regression >0.95 and with absolute average relative errors< 20%. After validation the methods were applied to several clinical applications: a total hip replacement simulation, fractured risk assessment and to investigate the effect of hallux valgus correction on the second metatarsal [4]. For example, in Figure 1 fracture experiment in which load, strain and displacement are measured and p-FEA of the second metatarsal with ø2.5 mm distal hole, loaded at 15° are presented.
This V&V tool is in an advanced stage to be used in clinical computer-aided decision-making. Several clinical applications will be presented.

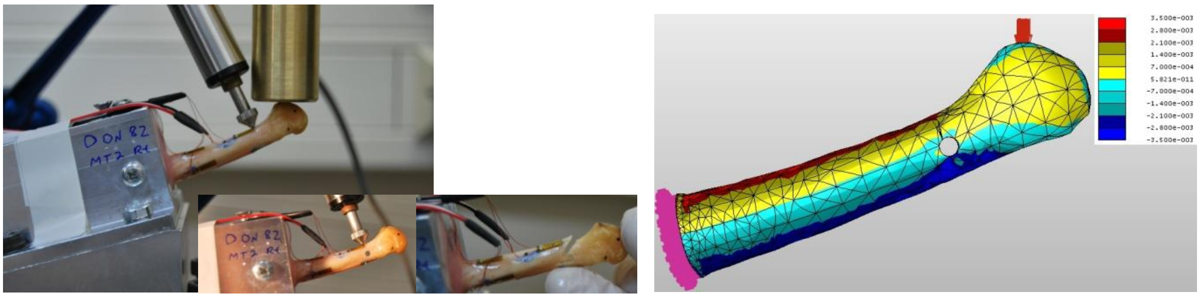

Fig 1. (Left) Experimental setup and fracture location in second metatarsal with ø2.5 mm distal hole, loaded at 15°. (Right) Strains computed by the FE analysis to estimate the yield load.

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