A COMPREHENSIVE BIOMECHANICAL ANALYSIS OF HEMIPELVIC CUSTOM-MADE RECONSTRUCTIONS IN THE LONG-TERM FOLLOW-UP

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Introduction

The resection of primary bone tumors around the acetabulum and consequent bone reconstruction presents major challenges. Computer-aided design and 3D-printed technologies made it possible to realize anatomical custom-made prostheses that include a porous structure with good short-term results (e.g. [1]).

Aim of the present work is to investigate whether mechanical issues may arise in the long-term follow-up that would suggest considering subject-specific biomechanical factors in the prosthetic design, in addition to the anatomical ones. To this aim we performed a comprehensive biomechanical analysis, in the long-term follow-up, on six patients that received an anatomical 3D-printed custom hemipelvic reconstruction after bone tumour.

We quantitatively estimated:

1) The functional recovery through motion analysis tests that reported a general optimal recovery with kinematic patterns not significantly different between limbs [2];

2) The asymmetry coefficient of the internal loads through personalized musculoskeletal (MS) modelling that showed instead a residual significant asymmetry in the loads between limbs [3];

3) The load distributions in the prosthesis and in the host bone during the two selected motor tasks of walking (most frequent) and squat (bilateral and challenging for reversed asymmetry indices that indicated higher loads on the operated limb), to evaluate the strain/stress distribution in the reconstructed pelvic ring (reported here)

Material and Methods

Six patients (4 males/2 females, aged 31 ± 7 yrs, BMI 22.6 ± 2.9 kg/m2, follow-up time 32 ± 18 months) with an anatomical custom-made 3D-printed prosthesis after pelvic bone sarcoma were included [4]. At the time of the control, patients performed state-of-the-art motion analysis (walking, stair ascent, stair descent, squat and chair rise/sit), and a pelvic CT scan.

State of the art FE models of the reconstructed pelvic ring were generated from the CT data. Bones and prosthesis were modelled with 10-noded tetra, ligaments with tensile-only trusses. Material properties of were derived from CT images for bone [5-8], and from literature for cartilage and ligaments [9-10].

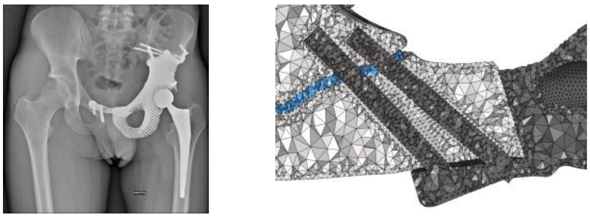

Figure 1: The RX of patient #3 and a particular of the corresponding FE model derived from CT data

Hip and muscles' forces (19 muscles per side, distributed over anatomical insertion area) were derived from the personalized MS models.

Results and discussion

Results from MS models indicated that, despite the optimal kinematic recovery, the internal loads were significantly shifted towards the intact limb (asymmetry index between 5% and 25% on av.), with the notable exception of the squat (18% higher peaks in the operated limb on av.) [3].

FE preliminary results (5 patients): i) the custom prosthesis is generally not at risk of fracture. Peak of flexural stresses were however registered in the small flaps used to close the pelvic ring; ii) the intact bone always remains in safety conditions; ii) the residual bone does not show concerning strain concentrations, on the contrary it is generally shielded by the prosthesis that results to be too stiff, despite its trabecular structure. Values of strain energy density can be calculated to quantify the adverse bone remodeling probability.

In conclusion the preliminary results seem to indicate that there is room for improving the prosthetic design, in particular towards the development of a material structure that better resembles the mechanical bone properties and with particular attention on the small flap features that are used to close the pelvic ring, that seem to be the weakest prosthetic region in common activities.

References

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