FAST 3D RECONSTRUCTION FROM BIPLANAR X-RAYS OF THE LOWER LIMB USING A PARAMETRIC AND STATISTICAL MODEL: ACCURACY EVALUATION

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INTRODUCTION

In clinical routine, the lower limb's follow-up relies on conventional X-rays imaging which provides only a 2D view, with its projection bias. A Computerized Tomography Scan (CT-Scan) can be required for surgical planning. However this imaging modality provides a high radiation dose. Biplanar radiography based methods allow the 3D reconstruction with accuracy close to 3D CT-Scan [1], in standing position and with a low radiation dose. However, such methods have a time consuming disadvantage and the precision of clinical parameters calculation was sometimes too rough [2]. This study aims to propose a fast 3D reconstruction method of the lower limb from biplanar X-rays using a parametric and statistical model, providing a quantification of 3D clinical indices. An *in vitro* accuracy of the method was provided.

METHODS

Parametric model and statistical inferences: The reconstruction method is based on a Simplified Parametric Model (SPM), statistical inferences and a Morphorealist Parametric Model (MPM).

The lower limb SPM is described by geometric primitives (3D points, spheres, cylinders, segments…). Correlations between the parameters characterizing the geometry of the SPM were assessed using a database of 54 lower limb's 3D reconstructions that were obtained from biplanar X-rays using a previous reconstruction method [1]. This analysis led to define a statistical inferences system, describing the linear regressions between the geometrical parameters.

The MPM is obtained as follows: A 3D reconstruction model of lower limb was obtained from CT-Scan slices. This detailed model was regionalized and parameterized in agreement with the SPM. A Moving Least Squares based deformation method [3] is used to deform this model by changing the values of the descriptive parameters.

Reconstruction method: The operator is asked to digitize a few set of parameters in both X-rays (Figure 1A). Using the statistical inferences, these few parameters are used as predictors to estimate the others, providing an initial solution for the SPM and the associated MPM. This initial MPM is projected on the radiographs (Figure 1B). Next, the anatomic landmarks related to the descriptors of the model are manually adjusted and the model progressively "self improves": each time a parameter is corrected, it becomes a predictor and the remaining descriptors are statistically re-estimated. The resulting MPM (Figure 1C) allows the calculation of 3D clinical indices.

Method evaluation: 3D CT-Scan reconstructions were obtained from 11 cadaveric femurs. For the same femurs, 3D reconstructions were performed using the EOS[TM] low dose biplanar X-rays system (Biospace med, France) and the above mentioned fast method without final fine shape adjustment. The 3D reconstructions from X-Rays, performed by two operators, were compared with the CT-Scan ones. The method was evaluated in terms of reconstruction time, femoral shape accuracy, SPM geometrical parameters accuracy and clinical indices accuracy.
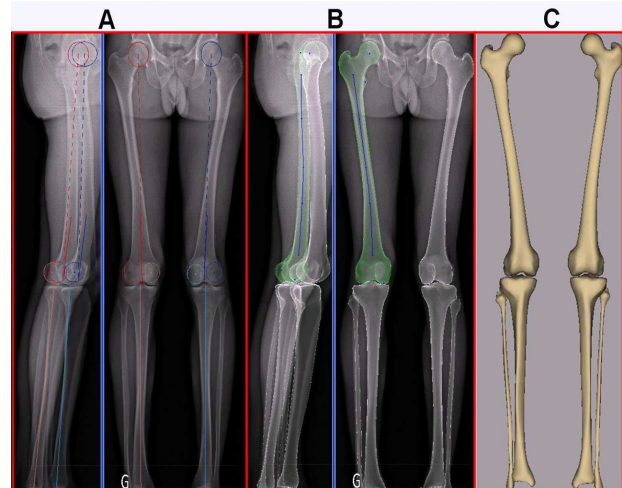

Figure 1: Different reconstruction steps.

RESULTS AND DISCUSSION

The mean fast method reconstruction time was 2min (max: 5min) for each femur. The mean femoral shape accuracy in comparison with the CT-Scan was 1.2mm showing a low significant bias. The 95% Confident Interval (CI) on the signed differences between the SPM geometrical parameters calculated on both reconstructions was between 1.2mm and 6.4mm. The 95% CI on signed differences between the clinical indices calculated on both reconstructions was between 2.0° and 6.0° (95% CI = 6° for the Neck-Shaft Angle).

CONCLUSIONS

A new reconstruction method was developed using statistical approach and a parametric model to obtain a fast estimation of the lower limb's 3D bony structures geometry in a standing position with a shape precision close to the CT-Scan reconstructions. This model allows obtaining 3D clinical indices with improvement in the assessment of femoral torsion with a precision (95% CI: 5.4°) better than for the CT-Scan [4]. Even without fine adjustment, such a method should be useful in clinical routine

REFERENCES

1. Laporte S, et al., *Comput Methods Biomech Biomed Engin* **6(1)**:1-6, 2003.
2. Schlatterer B, et al., *Rev Chir Orthop Reparatrice Appar Mot* (In press), 2009.
3. Cresson T, et al., *30th Inter Conf of the IEEE - EMBS*, **20-24**:3967-70, 2008.
4. Seber S, et al., *Arch Orthop Trauma Surg*, **120**:255-258, 2000.