MINIMAL DETECTABLE BONE FEATURES IN CT IMAGES AND DIGITAL 3D MODELS

Martin Frank (1,2), Andreas Strassl (3), Ewald Unger (2), Lena Hirtler (4), Barbara Eckhart (1), Markus Koenigshofer (2), Alexander Stoegner (1), Kevin Staats (1), Franz Kainberger (3), Reinhard Windhager (1), Francesco Moscato (2,5,6), Emir Benca (1)

1. Department of Orthopedics and Trauma Surgery, Medical University of Vienna, Austria; 2. Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Austria; 3. Department of Biomedical Imaging and Image-guided Therapy, Medical University of Vienna, Austria; 4. Center for Anatomy and Cell Biology, Medical University of Vienna, Austria; 5. Ludwig Boltzmann Institute for Cardiovascular Research, Austria; 6. Austrian Cluster for Tissue Regeneration, Austria

Introduction

Three-dimensional (3D) digital and additively manufactured models are increasingly used for pre-operative planning, and recently also for bone fracture treatment. However, the size minimum of detectable features in these models, including corresponding CT images, has not been determined yet. Hence, it remains unknown which features (e.g. fractures) might remain undetected. Therefore, this study aimed to investigate the minimal detectable bone features in CT images and corresponding digital 3D models

Methods

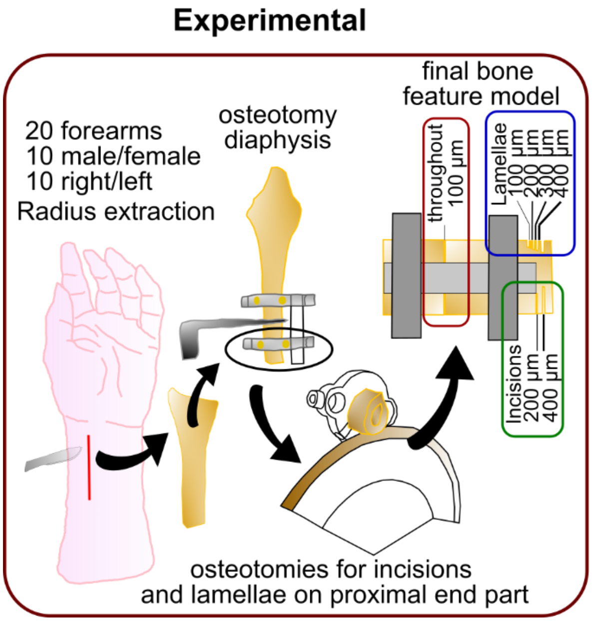

Figure 1: Experimental preparation of bone features (diaphyseal osteotomy, bone incisions, and bone lamellae)

Incisions in the diaphyseal radii with 200 and 400 µm width, and bone lamellae with 100, 200, 300, and 400 µm width were generated in twenty paired forearm specimens (78 ± 8 years (5 male and female, each)). Additionally, an osteotomy was performed in the diaphysis, aiming to simulate a complete fracture, and was displaced by a 100 µm fracture gap using specimen-specific, additively manufactured guides (Figure 1). Specimens were then scanned with different CT scanners and corresponding digital 3D models were created. The effects of different CT scanners, specimen positioning, scan and segmentation protocols, and image post-processing settings on feature detectability were assessed. Furthermore, inter- and intra-operator variabilities were reported.

Results

In CT images, all 300 and 400 µm incisions and bone lamellae could be identified at a rate of 80 to 100%, respectively, independent of the investigated settings. In contrast, only 400 µm incisions and bone lamellae were visible in digital 3D models. Hereby, the detection rate was independent of the scan settings (Figure 2) but dependent on the selected image segmentation and post-processing algorithms.

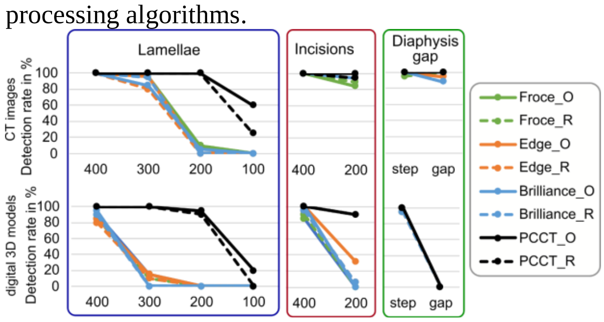

Figure 2: Fracture detection rate in CT images (top) and corresponding digital 3D models (bottom) for different CT scanners (SOMATOM Force, SOMATOM Edge Plus, photon-counting detector CT (NAEOTOM Alpha) (all Siemens), Diamond Select Brilliance64 (Philips). O: optimized protocol, R: routine protocol.

Discussion

Clinical CT imaging allows for the detection of bone features in sub-voxel range [1], independently of imaging settings. Thus, the choice of voxel-size and corresponding radiation exposure for diagnostic purposes should conform to the suspected fracture, its typical gap size and dislocation. Corresponding digital 3D models introduce higher inaccuracies (~voxel-size) and they should be verified with original CT images.

References

1. Kakinuma et al., PLoS One, 0(9):1–16, 2015.

Acknowledgements

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