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Topology optimization-based bone microstructure reconstruction from CT scan data

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ABSTRACT

For osteoporosis diagnosis, bone microstructure is considered as the most reliable measure of bone strength. However, there exist significant difficulties in representing *in vivo* bone microstructure due to the limited spatial resolutions of current clinical imaging devices such as CT and MRI. This study presents a novel method that can reconstruct bone microstructures from CT scan data, using the finite element analysis and topology optimization. Based on Wolff's law which states the self-optimizing capabilities of bone, topology optimization for compliance minimization is performed to reconstruct trabecular microarchitecture in the VOIs. A constraint for the BMD deviation is involved to maintain the patient-specific spatial bone distribution obtained from the quantitative CT (QCT) scan data. By doing so, the proposed method can enhance the QCT images of a 625μm resolution up to those of a 62.5μm resolution, which can precisely represent bone microstructure. To validate the proposed method, micro CT scan data of a 78.125μm resolution (reference) was downscaled to have a 625μm resolution. Then, they were upscaled to have an original resolution by using the proposed method. The reconstructed bone microstructure was compared with the reference in terms of image similarity, bone morphometric indices, and bone strength. This reveals a unique feature of anisotropic bone strength which the clinical CT scan data cannot provide. These results indicate that the proposed method can contribute to improving the accuracy of bone strength assessment and, therefore, can be a valuable tool for early osteoporosis diagnosis in the clinical field.

REFERENCES

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