FRACTURE TOUGHNESS OF CANCELLOUS BONE TISSUES USED FOR THE MANUFACTURING OF HETEROLOGOUS BONE GRAFTS

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Introduction and aim

As the number of bone defects caused by pathologies or traumas has constantly increased over time, medical devices (bone grafts) aimed at promoting tissue regeneration have been raising interest both in scientific and clinical literature. Whereas autologous bone is still regarded as the gold standard, the possibility to resort to perfectly compatible substitutes - among which heterologous bone (of mammalian origin) stands out - avoiding material harvest in patients and eventual surgical complications, is taken into high account in clinical practice. Several studies investigated the biological and medical features of the heterologous bone tissues used in grafts; however, literature about their mechanical behaviour is quite limited and a comprehensive research on their structural integrity is still lacking.

In this work, the fracture behaviour of trabecular bone tissues used for the manufacturing of commercial heterologous bone grafts was investigated, under the framework of fracture mechanics (FM). The applicability of the FM testing schemes proposed in the literature for the measurement of fracture toughness parameters was critically reviewed, and specific structure-property relationships researched.

Methods and results

The bone tissues examined were supplied by Bioteck S.p.A., an Italian company that deals with the research and production of tissue substitutes for regenerative medicine. They were obtained from equine bones after a specific proprietary enzymatic-based treatment aimed at achieving perfect biocompatibility while preserving the collagenous part. Two different tissues, both obtained from the femur, were examined. One had the mineral content of the bone of origin (F), whereas the other was markedly demineralized (FF). Tissue macro-structure and mechanical response under compression are presented in [1].

For the fracture characterization, Single-Edge notched in Bending, SE(B), tests were performed in quasi-static conditions and at room temperature. Specimens with two different sizes were tested. In consideration of the peculiar nature of these materials, special attention was paid to: (i) the specimen notching phase, necessary to introduce an artificial defect as sharp as possible replicating a natural crack, while preserving the region ahead of the crack tip from being damaged; (ii) the execution of correction tests necessary to take into account specimen indentation occurring during the fracture test, especially for FF tissue; (iii) the determination of a point that could be considered representative of fracture initiation in the fracture test.

The fracture response turned out to be remarkably dependent on whether the tissue was demineralized or not (see Figure 1). The denser and stiffer F tissue showed a brittle behaviour, which was studied by resorting to the Linear Elastic FM model. On the contrary, the highly-compliant FF tissue showed a markedly ductile response, requiring the use of the Elastic Plastic FM model. Fracture toughness data from representative specimens of F and FF tissues, expressed as critical stress-intensity values (at fracture initiation), $K_{I,c}$ and $K_{I,c\text{-}J}$, respectively, are indicated in Figure 1, together with the corresponding apparent density values. $K_{I,c\text{-}J}$ is the equivalent stress-intensity value, back-calculated from J_{Ic} as reported in [2]. The relationship between fracture toughness and tissue density was researched and discussed also in the light of the micro-structural characteristics of the tissues specifically investigated.

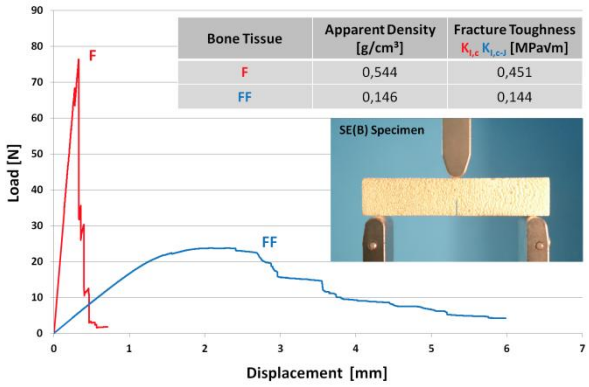

*Figure 1: Loading curves from fracture tests on representative **F** and **FF** SE(B) specimens with nominal thickness of 10 mm, width (W) of 20 mm, and tested with span-to-W ratio of 4. The corresponding fracture toughness data are also indicated.*

References

1. Agnelli et al, Biomedical Engineering Advances (in press)
2. Ritchie et al, Bone, 43:798-812, 2008

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