Measuring Fracture Toughness in Biological Materials

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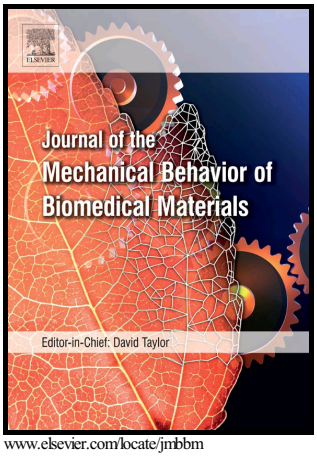

www.elsevier.com/locate/jmbbm

PII: S1751-6161(17)30295-3
DOI: http://dx.doi.org/10.1016/j.jmbbm.2017.07.007
Reference: JMBBM2406

To appear in: *Journal of the Mechanical Behavior of Biomedical Materials*

Received date: 26 April 2017
Revised date: 21 June 2017
Accepted date: 4 July 2017

Cite this article as: David Taylor, Measuring Fracture Toughness in Biologica Materials, *Journal of the Mechanical Behavior of Biomedical Materials* http://dx.doi.org/10.1016/j.jmbbm.2017.07.007

Measuring Fracture Toughness in Biological Materials

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Abstract

Many biological materials fail by cracking. Examples are bone fractures, contact damage in eggs, splits in bamboo culm and defects in cartilage. The mechanical property that best describes failure by cracking is fracture toughness, which quantifies the ease with which cracks propagate and defines a material's tolerance for pre-existing cracks and other stress concentrating features. The measurement of fracture toughness presents some challenges, especially for biological materials. To obtain valid results requires care and, in many cases, considerable ingenuity to design an appropriate specimen and test protocol. Common mistakes include incorrect interpretation of the mechanics of loading in unusual specimen designs, and failures occurring at the material's ultimate tensile strength as a result of specimens or cracks being too small. Interpretation of the resulting toughness data may also present challenges, for example when R-curve behaviour is present. In this article, examples of good and bad practice are described, and some recommendations made.

Keywords: fracture toughness; crack; eggshell; cuticle; soft tissues; cartilage; bone

Introduction

Toughness is an important property for any structural material, but it is a property which is difficult to define and measure. It is a relatively recent invention, first defined in the 1920's and not introduced into engineering practice until the 1960's. The need for this parameter becomes clear when we note that there are some materials which have good strength and toughness and yet fail easily. Examples of these materials are glasses and engineering ceramics such as alumina and silicon carbide. Measurements of

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