Indentation Testing to Determine Bone Fracturability

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Advances in fundamental understanding of bone fracture have led to the possibility of determining bone fracturability from a new method of indentation: Reference Point Indentation, RPI. A primary goal of the field is to establish the scientific basis for the method and to conduct laboratory testing to illuminate the differences between more and less easily fractured bone. Though bone is a hierarchically structured material with levels of hierarchy all the way from nanometers to meters, it is becoming clear that the distance range from 100 nm to 100 um is critical. Indentations with a 90 degree conical indenter with depths of order 100 um are sufficient to open and propagate microscopic cracks in this critical distance range[1]. A Reference Point Indentation, RPI, instrument can perform indentation measurements in this critical distance range not only in the laboratory, but also on living patients[1,2]. Scientists and physicians are beginning to investigate the relation between these new indentation measurements and more established mechanical testing. For example, there is an inverse correlation between R curve analysis of crack propagation and a new parameter, Indentation Distance Increase, IDI, measured with a Reference Point Indentation instrument[1]. The Reference Point Indentation instrument measures IDI by cycling a conical indenter tip into the bone multiple times (typically 20 times at 2 Hz) at the same location[2,3]. The IDI is defined to be the difference between the indentation distance of the final cycle and the indentation distance of initial cycle. The observed correlation can be explained by the hypothesis that both the R curve analysis and the IDI measure the susceptibility of the bone to crack propagation: if cracks propagate more easily the slope of the R curve will be less and the IDI will be greater. Other laboratory studies[3,4,5] have established other correlations between Reference Point Indentation measurements and established mechanical testing. A frontier is developing methods for using Reference Point Indentation on horses, mice and other animals. Seminal work with RPI from the laboratories of Mary Bouxsein demonstrating differences between different mouse strains[6], Tamara Alliston quantifying the degradation of stratified cartilage material properties in osteoarthritis[7], and Michelle Dickenson showing the changes in bone properties between bone hydrated in vivo, hydrated in vitro and dried in vitro[8] will be discussed.

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