MEASURING CORTICAL BONE STIFFNESS USING MICRO-INDENTATION

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Introduction: The increase in revision joint replacement surgery and fractures of bone around orthopaedic implants may be partly addressed by keeping bone healthy around orthopaedic implants by inserting implants with mechanical properties closer to the patient's bone properties. We do not currently have an accurate way of calculating a patient's bone mechanical properties. We are therefore investigating whether microindentation can accurately calculate bone stiffness.

Methods: We received ethical approval to retrieve femoral heads and necks from patients undergoing hip replacement surgery for research. Cortical bone from the medial calcar region of the femoral neck was cut into 3x3x6mm cuboid specimens. Micro-indentation testing was performed in the direction of loading of the bone using a MicroMaterials indenter. The samples were kept hydrated and were not fixed or polished. From the unloading curve after indentation, the elastic modulus was calculated, using the Oliver-Pharr method. To assess which microindentation machine settings most precisely calculate the elastic modulus we varied the loading and unloading rates, load and indenter tip shape.

Results: The most precise results were obtained by using a spherical indenter tip (rather than Berkovich tip), high load (10N), a loading rate of 100 mN/s and unloading rate of 300 mN/s with a pause of 60 seconds at maximum load and multiple load cycles with constant loads. Using these settings the mean elastic modulus over 12 cycles of testing was 13.0 GPa (+/- 2.47).

Discussion: By using a spherical indenter tip and fast unloading it was possible to get precise apparent modulus values. By unloading as fast as possible the effects of bone viscoelastic properties are minimised. By using a spherical indenter tip, plastic deformation at the tip is minimised (compared to the Berkovich tip). We are performing further standard compression tests on the samples to verify the accuracy of the indentation tests.