USING AN EQUIVALENT SURFACE TO QUANTIFY CONGRUENCE AND CONTACT VARIABILITY IN JOINTS

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Introduction

The level of congruence (or geometric conformity), between the articulating surfaces of a synovial joint can vary substantially between people. It has been hypothesised that a more incongruent instance of a joint could be more at risk of developing osteoarthritis [1]. However, previous methods of quantifying congruence have required detailed mathematical descriptions of the articulating surfaces and their relative position [2,3]. In this talk, we will: (1) share a recently published new method of measuring joint congruence [4], that works directly from the 3D segmented points clouds; and (2) show how the concept of an 'equivalent surface' (employed in our new method) has inspired application of statistical shape modelling to the variability of articular contact.

Materials and Methods

The first step of our new methodology is performing a finite element (FE) simulation of an elastic layer compressed between each set of segmented bones. The results of this are then interpreted using the elastic foundation model (Figure 1), enabling an equivalent, but simpler, contact geometry to be identified. From this, the equivalent radius (quantification of joint congruence) is found. This defines the radius of a sphere contacting plane (or "ball on flat") that produces an equivalent contact to that in each joint. The minimal joint space width (in this joint position) can also be estimated from the FE simulations. The new method has been applied to ten healthy instances of the thumb metacarpophalangeal (MCP) joint.

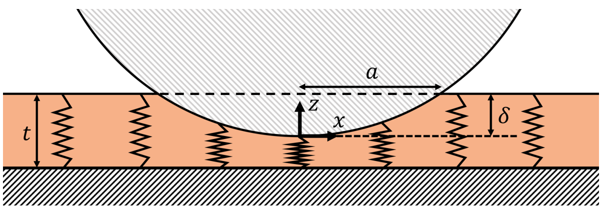

Figure 1: Elastic foundation model: an elastic layer between two rigid surfaces is modelled as a set of independent springs. [4]

Results

The ten thumb MCPs had similar levels and variability of congruence as other diarthrodial joints that have been characterised previously [5] and showed no relationship between congruence and joint space width (Figure 2).

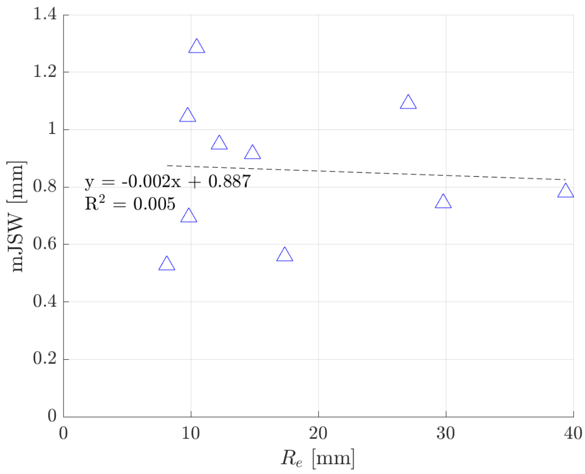

Figure 2: Relationship between minimal joint space width (mJSW) and equivalent radius (Re). [4]

Discussion

The new method can be used to perform efficient quantification of congruence directly from CT- or MRI-derived bone geometry in any relative orientation, lending itself to large data sets and coupling with kinematic models. However, we believe there is more that can be exploited from the concept of an equivalent surface, which is fundamental to this quantification of joint congruence.

Current work focusses on generating a Statistical Shape Model (SSM) to describe the dominant modes of variation of the equivalent surface generated in each of the ten healthy thumb MCP joints. Using a SSM methodology, it is possible to better understand joint contact variation rather than interrogate the whole bone geometry.

References

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