THE ACCURACY AND RELIABILITY OF A NOVEL HANDHELD DYNAMIC INDENTATION PROBE FOR ANALYSING ARTICULAR CARTILAGE

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Introduction: A close correlation between the mechanical properties of articular cartilage (AC), and the structural and biochemical integrity of the extracellular matrix has been established [1]. With the suggestion that an alteration in the biomechanical properties of AC may be a good indicator of early stage degeneration, our aim was to develop a system that was capable of measuring the dynamic indentation properties of soft tissue. Accuracy, intra-operator and inter-operator reliability of the system were investigated. The system was then used to assess the topographical variation in dynamic and static biomechanical properties of AC of aged ovine tibial plateaux (n=6).

Materials and methods: Animal model. Six aged (7-year-old) female ovine were sacrificed. Tibial plateau osteochondral sections were removed from the long bones and the sections wrapped in saline soaked gauze. Experimental apparatus. The dynamic indentation instrument incorporated a plastic handle with a 170mm long stainless steel tube (5mm external diameter) extending from one end. Located at the end of the tube was a vibration unit with a small probe (0.5mm diameter) attached, which extended out of the side of the tube. A single frequency waveform (20Hz) was applied to the instrument causing the probe to vibrate. The probe was pressed against the AC surface under moderate pressure and the dynamic biomechanical properties collected. Topographical assessment of AC. Six tibial plateau osteochondral sections were investigated. A 3 x 3 array was marked on the AC surface of the lateral and medial tibial compartments [2]. Indentation tests were conducted at each marked location (n=18) and the dynamic stiffness, phase lag and static force of the tissue collected. On completion of the indentation assessment, the thickness of the AC was measured using a needle penetration method. The dynamic shear modulus, was calculated using Hayes et al., equations [3]. Accuracy and Reliability study. The accuracy of the indentation system was assessed by testing a range of silicon elastomers (n=4) and comparing with a bench-top oscillatory system [5]. In conclusion, we believe this handheld indentation system is a highly reproducible and accurate tool for rapidly assessing the biomechanical properties of AC. The system is small enough to be inserted into a human or animal knee joint under arthroscopic control, and with further development, may be used clinically to assess the viability of the AC and other soft tissue in-situ.

Table II: The intra-operator reliability of the hand-held dynamic indentation system.

<table>
<thead>
<tr>
<th>Intra-class correlation coefficient (Rho)</th>
<th>95% Confidence interval</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic stiffness</td>
<td>0.79</td>
<td>0.61-0.92</td>
</tr>
<tr>
<td>Phase lag</td>
<td>0.09</td>
<td>0.05-0.37</td>
</tr>
<tr>
<td>Static force</td>
<td>0.52</td>
<td>0.25-0.77</td>
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</tbody>
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Topographical variation in dynamic response of tibial plateau AC. Figure 1 presents the mean dynamic shear modulus of six ovine tibial plateaus. It can be seen that the AC that was situated beneath the lateral and medial menisci demonstrated a significantly higher dynamic moduli than the AC situated in the unprotected region of the tibial plateau. No significant topographical difference in phase lag was found (results not show).

Discussion The results of this study show that the handheld dynamic indentation system was an accurate and reliable tool for assessing the topographical biomechanical properties of AC in-vitro. The dynamic stiffness was found to be the most reliable measure for distinguishing between various regions across a normal tibial plateau with excellent inter and intra-correlation coefficients. Static loading was found to be unreliable for assessing topographical variation. This inconsistency was mainly due to significant fluctuations in the static force signal, as a result of inconsistent loading and movement of the instrument by the different operators. The phase lag was found to be near constant (10-12°) over the entire plateau, which was comparable to the phase lag of normal bovine AC as established using a bench-top oscillatory system [5]. In conclusion, we believe this handheld indentation system is a highly reproducible and accurate tool for rapidly assessing the biomechanical properties of AC. The system is small enough to be inserted into a human or animal knee joint under arthroscopic control, and with further development, may be used clinically to assess the viability of the AC and other soft tissue in-situ.

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References:

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