INTRODUCTION
Clinical laxity tests are frequently used for assessing knee ligament injuries and for soft tissue balancing in total knee arthroplasty (TKA). Current routine methods are highly subjective with respect to examination technique, magnitude of clinician-applied load and assessment of joint displacement. For collateral ligament injuries, scoring systems to grade severity are often based on millimetres of perceived joint opening with applied manual stress, so are highly reliant on clinician judgement. In TKA, assessment of laxity is a routine component of soft tissue balancing techniques and is often used to determine the need for a soft tissue release [4]. Alignment measurements generated by computer-assisted technology have led to the development of quantitative TKA soft tissue balancing algorithms which are often based on tibiofemoral angular displacements with applied varus and valgus stress [2]. However, to make full use of the technology and to make the algorithms applicable in practice, the methods used to obtain the measurements require standardisation.

With the high incidence of soft tissue knee injuries and the growing physical demands of TKA patients, there is a potential role for improving the evaluation of knee laxity. The development of a quantitative assessment technique for incorporation into current routine practice requires accurate standardisation of several parameters. The knee flexion angle should be determined and then maintained during the testing to minimise the potential positional variation in ligament restraining properties [3]. The hand positioning of the examining clinician should correspond to a measured lever arm, defined as the perpendicular distance of the applied force from the rotational knee centre. Accurate measurement of this manual force is then required to calculate the moment applied to the knee joint. Finally, the resultant displacement of the knee should be quantified as a measure of ligament laxity. The aim of this study was to determine whether different clinicians can reliably assess coronal knee laxity when these variables are standardised. In addition we aimed to evaluate the specific effect of introducing a manual force application device. We hypothesised that standardisation of the clinical laxity test would result in a narrow range of laxity measurements obtained by different clinicians.

METHODS
Six consultant orthopaedic surgeons, six orthopaedic trainees and six physiotherapists were instructed to assess the coronal laxity of the right knee of a healthy volunteer. Points were marked over the femoral epicondyles and the malleoli to indicate hand positioning, so that the moment arm was constant. The right hand of the participant was always the ‘pushing hand’ while the left hand was used to stabilise the distal thigh.

The non-invasive adaptation of the Orthopilot® (Aesculap/B. Braun, Tuttingen, Germany) image-free navigation system enabled real-time measurement of coronal and sagittal mechanical femorotibial (MFT) angles. This has been previously validated to an accuracy of ±1° [1]. Collateral knee laxity was defined as the amount of angular displacement, following a stress manoeuvre which was automatically recorded by the system. Participants were instructed to maintain the knee joint in 2° of flexion as indicated by the computer screen whilst performing a varus-valgus stress test using what they perceived as an acceptable load. They were blinded to the coronal MFT angle measurements.

A hand-held force application device (FAD) [1] was employed to allow the clinicians to apply a pre-determined moment of 18Nm. This level was determined from previous work. They were instructed to perform the varus-valgus stress test using the device in the palm of their right hand and to apply the force until the visual display and an auditory alarm indicated that the target had been reached. The applied moment was continuously recorded enabling a measurement of overshoot of the target moment. The FAD was then removed and participants were asked to repeat the clinical varus-valgus stress test, but to try and apply the same amount of force as they had been doing with the device.

MFT angular deviation was recorded for each test and the maximum moment applied was recorded for each of the tests using the FAD. Finally, clinicians were asked for open feedback on their perceived use of the FAD and comparison to their normal practice. Means and standard deviations (SD) were used to compare different clinicians under the same conditions. Paired t-tests were used to measure change in practice of groups of clinicians before, during and after use of the FAD for both varus and valgus stress tests.

RESULTS AND DISCUSSION
Table 1 shows the mean varus and valgus laxity (± SD) measured by each group of clinicians. All three groups of clinicians initially produced measurements of valgus laxity with consistent mean values and standard deviations (<1°). For varus mean values were consistent but standard deviations were larger.

When using the FAD, the standard deviations remained low for all groups for both varus and valgus laxity. The most
significant change was for trainees assessing varus laxity whereby the SD reduced from 1.6° to 0.9°. Introducing the FAD overall produced a significantly greater valgus angulation (p<0.001) but not for varus (p=0.67), when compared to the initial clinical examination. This was re-enforced by clinicians, one third of whom commented that they felt they had to push harder for valgus than varus, despite the target being the same. In attempting to reach the target moment of 18Nm, the mean ‘overshoot’ was 0.9Nm for both varus and valgus tests. Almost half of the participants stated that the force required for the FAD was more than they would routinely use in practice and were concerned about the volunteer feeling pain, which was not reported in any case.

This upper limit was chosen for a healthy volunteer and we expect would be more than that normally used when examining an osteoarthritic knee.

After having used the FAD the standard deviation was less than 1.3° across all the groups for both varus and valgus. The consultants’ performance remained consistent and valgus assessment remained consistent for all groups. Standard deviations for varus laxity were lower for all groups following use of the FAD. The only significant change in practice for a group before and after use of the FAD was for the trainees testing valgus, who may have been trained to push harder (p=0.01).

We have shown that controlling the subjective variables of clinical examination provides a repeatable, quantitative technique, which appears more consistent for valgus laxity than for varus. This may lead to improved balancing techniques in TKA through quantification of knee laxity before, during and after surgery enabling a more widespread use of single surgeon-derived algorithms [2]. There is a potential role in the management of collateral ligament injuries with regard to more reliable initial diagnosis and severity grading as well as more targeted recovery and rehabilitation.

Finally, we have demonstrated that clinicians can use the FAD to apply pre-determined forces, without compromising repeatability. In addition, following FAD use, the results suggest that more experienced clinicians return to applying their usual manual force, while trainees appear to use this augmented feedback to adapt their technique. Therefore quantifying the technique of senior clinicians may help to enhance the perceptive skills of more junior trainees who do not have the benefit of experience.

**CONCLUSIONS**

We have successfully quantified and standardised the manual technique of coronal knee laxity assessment. Our hypothesis stated that this would lead to a narrow range of laxity measurements, which our results have supported within the accuracy limits of our non-invasive navigation system. This study shows that incorporating a force application device into assessment of coronal knee laxity did not affect the clinicians’ ability to produce reliable and repeatable measurements, despite removing the manual perception of laxity. The FAD also provided additional information about the actual moment applied. This information may have a role in improving the balancing techniques of TKA and the diagnosis of collateral ligament injuries.

**REFERENCES**


**Table 1:** Mean varus and valgus laxity (degrees ± SD) measured by each group of clinicians

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Physios</th>
<th>Consultants</th>
<th>Trainees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Varus</td>
<td>Valgus</td>
<td>Varus</td>
<td>Valgus</td>
</tr>
<tr>
<td>Before</td>
<td>5.4 (±1.3)</td>
<td>1.6 (±0.6)</td>
<td>5.9 (±1.6)</td>
<td>1.5 (±0.5)</td>
</tr>
<tr>
<td>FAD</td>
<td>5.3 (±1.2)</td>
<td>2.4 (±0.6)</td>
<td>5.1 (±1.5)</td>
<td>2.3 (±0.5)</td>
</tr>
<tr>
<td>After</td>
<td>5.5 (±1.2)</td>
<td>1.9 (±0.7)</td>
<td>6.1 (±1.3)</td>
<td>1.7 (±0.4)</td>
</tr>
</tbody>
</table>