Non-invasive assessment of lower limb alignment is accurate for pre-operative planning and post-operative follow up

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Introduction: Knee alignment is a fundamental measurement in the assessment, monitoring and surgical management of patients with OA. Recent controversy about the effect of knee alignment on long term TKA survivorship [1] has revived the debate about the effective measurement of knee alignment. In the absence of validated alternatives, leg alignment is commonly assessed with either short knee or long leg radiographs, both of which may be inaccurate due to limb positioning errors. Three dimensional CT or MRI imaging may provide more accuracy but can only measure alignment as a static parameter in the supine position. To overcome these limitations, we have developed a non-invasive measurement technique with the view to more accurately assessing knee alignment under a number of dynamic, real-time conditions [2].

The purpose of this study was to compare non-invasive supine alignment measurements in osteoarthritic and prosthetic knees taken pre- and post-operatively to those data gathered intra-operatively using standard invasive methods. The hypothesis was that the clinical measurements would be accurate enough to enable pre-operative planning and longer term follow-up.

Materials & Methods: A non-invasive infrared position capture system (accuracy ±1° in coronal and sagittal planes) [2] was used to assess knee alignment for 31 patients with OA, before and at six weeks following TKA. Coronal and sagittal mechanical femorotibial (MFT) angles in extension were measured supine with the lower limb supported at the heel and the subject asked to relax. Varus-valgus stresses were applied to the knee and the resultant MFT angles recorded. Intra-operatively the same data were collected both pre- and post-implant as per standard practice. This gave data from the invasive and non-invasive systems for both osteoarthritic (OA) and prosthetic (TKA) knees which were compared using paired t-tests.

Results: For both OA and TKA knees, the mean difference in coronal MFT angle between non-invasive and invasive measurements was small (0.5°) and not clinically or statistically significant (Table 1). For the sagittal MFT angles there was a significant difference between non-invasive and invasive measures for both OA and TKA knees (Table 1). For OA knees, the intra-operative measurements were in greater relative extension (mean -5.2°) compared to the non-invasive measurements. The post-implant TKA invasive measurements had an even greater tendency (-7.2°) to more extension compared to the non-invasive post-operative clinical measurements.

For OA knees, both varus and valgus stress manoeuvres resulted in statistically greater angular displacements for invasive measurements (mean differences 1.5° more varus and 1.6° more valgus) compared to non-invasive measures (Table 2). For TKA knees, the valgus angular displacement was statistically greater for invasive intra-operative measurements but for varus angular displacement the two measurement conditions were statistically similar with a mean difference of 0.3° (Table 2).

Conclusions: The invasive OA and TKA coronal MFT angles were more valgus than the corresponding non-invasive measurements by a mean difference of 0.5°. This trend, although neither clinically or statistically significant in the context of overall knee alignment, may have represented the effect of the medial surgical exposure in most cases with potential loss of valgus restraint. In contrast to the coronal measurements, the sagittal MFT angles were significantly different for clinical and operative conditions. In the pre-operative clinical setting, muscular contraction could have potentially restricted the amount of knee extension if this was painful. The removal of this muscular inhibition along with exposure of the knee resulted in a more extended intra-operative position. This was a similar finding in the TKA group, with an even greater degree of relative hyperextension for the invasive measurements.

		mean(95%CI) ±SD	
		OA (n=31)	**TKA (n=29)**
Supine coronal MFT angle (°)	**Non-invasive**	-2.5(-4.6, -0.4) ±5.7	-0.7(-1.2, -0.1) ±1.4
	Invasive	-2.0(-4.0, 0.2) ±5.7	-0.2(-0.6, 0.2) ±1.1
	Difference	0.5(-0.5, 1.5) ±2.8	0.5(-0.1, 1.0) ±1.4
	p value	0.3	0.08
Supine sagittal MFT angle (°)	**Non-invasive**	7.7(5.1, 10.4) ±7.1	6.7(4.8, 8.7) ±5.1
	Invasive	2.5(-0.3, 5.3) ±7.7	-0.5(-1.8, 0.7) ±3.3
	Difference	-5.2(-6.8, -3.7) ±4.3	-7.2(-9.0, -5.4) ±4.7
	p value	<0.001	<0.001

Table 1: Comparison of non-invasive and invasive alignment measurements for pre-operative (OA) and post-operative (TKA) patient groups. Negative values indicate varus in coronal plane and hyperextension in sagittal plane.

		mean(95%CI) ±SD	
		OA (n=30)	**TKA (n=28)**
Varus angular displacement (°)	**Non-invasive**	-3.8(-4.4, -3.3) ±1.5	-4.3(-4.8, -3.9) ±1.1
	Invasive	-5.3(-6.3, -4.5) ±2.2	-4.1(-4.6, -3.5) ±1.4
	Difference	-1.5(-2.4, -0.6) ±2.4	0.3(-0.3, 0.8) ±1.4
	p value	0.002	0.3
Valgus angular displacement (°)	**Non-invasive**	3.3(2.7, 3.9) ±1.6	2.8(2.5, 3.1) ±0.8
	Invasive	5.0(4.4, 5.5) ±1.6	3.7(3.2, 4.2) ±1.3
	Difference	1.6(1.1, 2.2) ±1.6	0.9(0.4, 1.4) ±1.3
	p value	<0.001	0.002

Table 2: Comparison of non-invasive and invasive coronal laxity for pre-operative (OA) and post-operative (TKA) patient groups

During pre-operative clinical assessment, the limiting factor during stress testing may have been the discomfort of the manoeuvre rather than the perception of a definitive end-point. Therefore muscular inhibition during stress testing, which was absent intra-operatively, most likely accounted for the greater overall mean values of the invasive measurements. The effect of the medial exposure of the knee may have influenced the degree of valgus angular displacement, although the magnitude of the difference between non-invasive and invasive measurements was the same for both medial and lateral laxity. Following TKA the trends suggest that the difference between the intra-operative and post-operative valgus stress measurements was not the result of pain inhibition as this same trend would have then been expected. The results suggest that the intra-operative varus laxity is likely to be the same when measured at the six week post-operative stage. However the intra-operative valgus laxity may be around 1° less when measured at six weeks. This could have been due to the effect of wound closure with contraction of the medial tissues as part of the normal acute healing process [3].

Overall the measurements taken in the clinic would have enabled accurate pre-operative planning as long as the increase in extension seen intra-operatively was accounted for. Surgeons may be advised that post-operatively the extension seen is less than that measured post-implant and to adjust their aims accordingly. Further investigations are now envisaged using this reliable system to assess lower limb alignment to determine whether intra-operative outcome is maintained over the time.

References

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