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Comparison of a Novel Joint Distraction Radiology Protocol in Total Knee Arthroplasty Planning with Navigated Joint Gaps

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Abstract

Native extension and flexion joint gaps are primarily measured intraoperatively using devices such as navigation systems or tensioners, but there are advantages to being able to pre-operatively plan to such gaps. This study aims to validate the ability of a novel distracted joint gap radiology protocol to measure pre-operative extension and flexion joint gaps.

A retrospective study comprised of 42 knees was performed. Patient imaging was obtained and used to perform segmentation, landmarking and 3D-to-2D registration. The pre-operative medial and lateral joint gaps were determined in extension and flexion. Intraoperatively, a range of motion analysis was conducted using the Brainlab Knee 3 navigation system to measure the joint gaps in extension and flexion.

In extension, both medial and lateral pre-operative radiological and intraoperative navigated gaps displayed moderate and statistically significant correlations ($r=0.45$; $p=0.003$ for medial and $r=0.4$; $p=0.01$ for lateral). In flexion, only the medial radiological and navigated joint gaps correlated ($r=0.54$, $p<0.001$), with a not statistically significant trend for the lateral flexion joint gaps.

The moderate and statistically significant correlations between these joint gaps to those measured intraoperatively suggests they are reflective of on the table experience with patients. Although further work is required to understand if differences are attributable to variability in the radiological or intra-operative assessments, the pre-operative analysis technique described in this study provides the opportunity to develop a more holistic pre-operative surgical plan which considers the state of both hard and soft tissue within the joint.

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1 Introduction

A goal of Total Knee Arthroplasty (TKA) is to obtain a balanced extension and flexion gaps to facilitate in the restoration of joint kinematics. This can enhance patient outcomes in the form of post-operative satisfaction[1], proprioception[2] and range of motion[3]. Native extension and flexion joint gaps are primarily measured intraoperatively using devices such as navigation systems or tensioners, but there are advantages to being able to pre-operatively plan to such gaps. This study aims to validate the ability of a novel distracted joint gap radiology protocol to measure pre-operative extension and flexion joint gaps.

2 Methods

A retrospective study comprised of 41 patients totaling 42 operated knees (1 bilateral) was performed. All patients were recruited from an experienced orthopaedic surgeon between March 2020 and October 2020. A long-leg supine CT scan and two distracted weighted knee X-rays (one each in extension and flexion) were taken pre-operatively. Landmark localization and segmentation were performed on the CT scan, followed by 3D-to-2D registration of the bone models onto the extension and flexion X-rays. These registered 3D models were used to measure the pre-operative medial and lateral joint gaps in both extension and flexion. Intraoperatively, a range of motion analysis was conducted using the Brainlab Knee 3 navigation system to measure the joint gaps in extension and flexion. Navigated joint gaps were captured following an attempt to remove all soft tissue tenting osteophytes, while the radiological protocol made use of an algorithm to remove the impact of tenting from its gap analysis. Statistical analysis was performed in R Studio v1.3.1903. This retrospective analysis was approved by the Bellberry Human Research Ethics Committee (study number 2012-03-710).

3 Results

Of the 42 joints, 50% (21) were female, with the mean patient age of 70.3 ± 7.3 years at the time of surgery. In extension, both medial and lateral pre-operative radiological and intraoperative navigated gaps displayed moderate and statistically significant correlations ($r=0.45$; $p=0.003$ for medial and $r=0.4$; $p=0.01$ for lateral). In flexion, only the medial radiological and navigated joint gaps correlated ($r=0.54$, $p<0.001$), with a not statistically significant trend for the lateral flexion joint gaps. These trends are displayed in Figure 1. The preoperatively obtained distracted gaps were observed to be smaller than the intraoperatively observed joint gaps (Figure 2).

4 Discussion

The imaging and registration technique outlined in this study allows for the pre-operative measurement of distracted joint gaps in extension and flexion. The moderate and statistically significant correlations between these joint gaps to those measured intraoperatively suggests they are reflective of on the table experience with patients. Although further work is required to understand if differences are attributable to variability in the radiological or intra-operative assessments, some

insights can be gained through existing literature. It has been previously established that there is variability in the surgeon assessment of joint balance, especially in flexion[4]. Soft-tissue balance and the resulting gaps are impacted by the extent of joint distraction forces applied[5]. Since the pre- and intra-operatively applied distraction forces were different, this may also contribute to the lack of a strong correlation between the two.

Current pre-operative planning approaches are often unable to account for soft-tissue information, especially regarding the ligament laxities. This study describes a technique to pre-operatively assess medial and lateral joint gaps in extension and flexion, which displays moderate correlation to the corresponding intraoperative joint gaps as observed with navigation. This provides the opportunity to develop a more holistic pre-operative surgical plan which considers the state of both hard and soft tissue within the joint.

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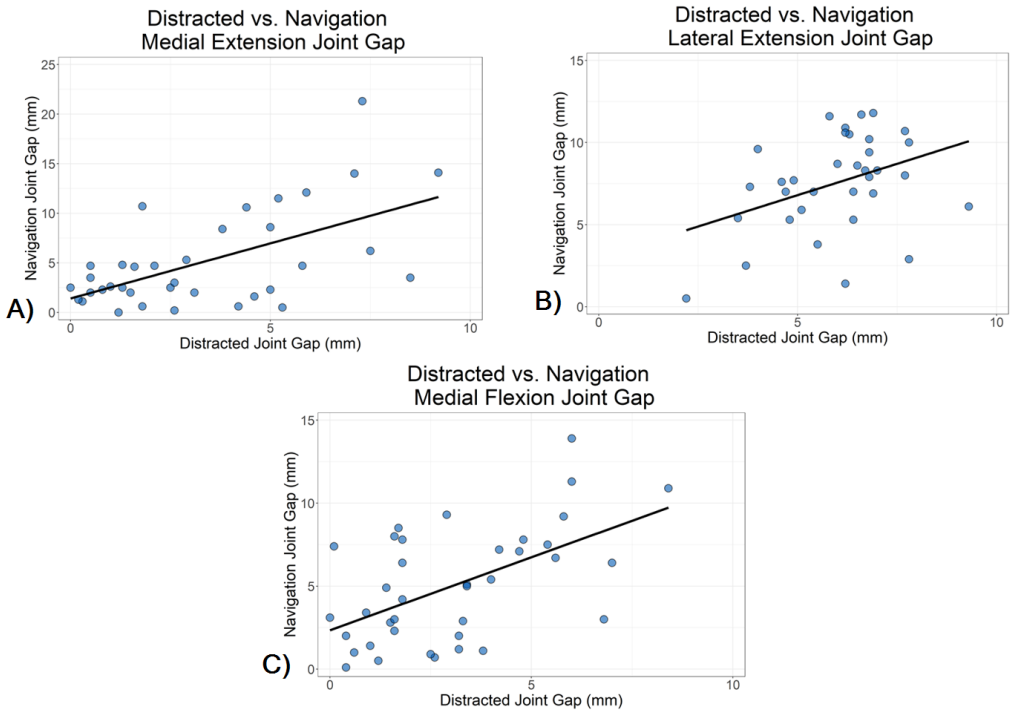

Figure 1. Plot of the pre-operatively obtained distracted joint gap against the intra-operatively observed navigation joint gap for the A) medial compartment in extension, B) lateral compartment in extension and C) medial compartment in flexion.

Joint position	Compartment	Distracted gap (mm)	Navigation gap (mm)	Correlation coefficient	P-value
Extension	Medial	3.1 ± 2.45	4.14 ± 5.10	0.45	0.003
	Lateral	5.62 ± 1.89	5.66 ± 4.80	0.40	0.01
Flexion	Medial	2.85 ± 2.16	4.45 ± 3.76	0.54	< 0.001
	Lateral	6.25 ± 2.04	6.23 ± 3.25	0.20	n.s.

Figure 2. Summary of the pre-operative (distracted) and intra-operative (navigation) gaps for the medial and lateral compartments in extension and flexion.