The impact of inadequate radiographic technique on the measurement of patellar height

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INTRODUCTION

The patellofemoral joint consists of the femoral trochlea and the patella, which track during knee flexion and extension. Stability of this joint relies on anatomical factors and biomechanical factors, including lower extremity alignment, patellofemoral kinematics, and patella height, also influence joint stability (1-3). Deficiencies in these anatomical and biomechanical factors can lead to patellofemoral instability (PFI), marked by recurrent patellar dislocations or subluxations (4). A high patella (patella alta) is associated with 30-50% of patellar dislocations (5) and can cause low-energy dislocations without trochlear dysplasia, making it a crucial factor in diagnosing and treating PFI (6).

Patellar height indices (PHI), such as the Blackburne-Peel, Insall-Salvati, and Caton-Deschamps provide methods for assessing patellar height using radiographs. These indexes require strictly projected lateral radiographs for accuracy, but in clinical practice, radiographs often have some degree of malrotation or tilting (Figure 1).

Currently, there is poor evidence on the effects of these radiographic malrotations and inclinations on the assessment of patellar heights indices and their potential influence on decision-making for patients with patellofemoral pathology, including considerations for surgical intervention (7).

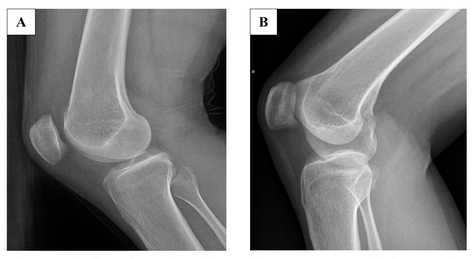


Figure 1. Two lateral radiographs are presented. Image A shows a strict lateral projection. Image B shows a soboptimal projection.

OBJECTIVES

The main objective is to evaluate whether the calculation of patellar height in poorly performed radiographs differs significantly from those obtained in correctly projections. Secondary objectives are to evaluate whether rotation or tilting has a greater impact on patellar height index measurements, to determine if any specific index is more susceptible to the effects of poor radiographic technique and to assess inter- and intra-observer reproducibility.

METHODS

This experimental and observational study compared strictly lateral radiographs with malrotated and/or tilted radiographs in each patient, serving as their own control. Data from the Complejo Hospitalario Universitario Insular y Materno Infantil (CHUIMI) were used, including 409 patients with at least two knee radiographs taken in 2022. Patients were selected if they had at least one strictly lateral radiograph and another malrotated or tilted radiograph, no prior knee surgery, and radiographs with a flexion degree within the range of 30° to 70°, excluding patellar fractures and opened physes.

The patellar height was assessed in the selected 33 patients using the Blackburne-Peel, Insall-Salvati, and Caton-Deschamps indices, allowing for a 95% confidence interval and a margin of error of 0.17. See Figure 2.

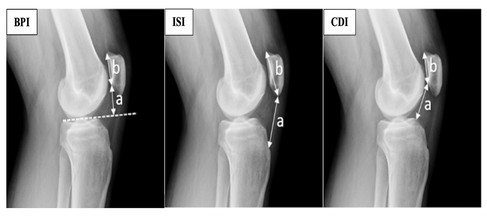


Figure 2. Representation of BPI, ISI, and CDI measurements (a/b) (8).

PHI of the radiographs were measured using the Horos program. The 66 radiographs were independently assessed in a randomized sequence by eight observers, which included four orthopedic surgeons specializing in knee surgery and four orthopedics and traumatology residents.

Measurements were conducted independently on two separate occasions, spaced at least one week apart. All observers were blinded to the patients' information, the results of their colleagues and their own previous measurements.

A linear mixed-effects model was used to analyze the data, considering fixed effects such as the quality of the radiographic projection, the observer's professional category and the observation time. Random effects included variability among physicians and patients. Variables are explained in table 1. Formally, the model is:

$$y_{IRCijkl} = \mu + \alpha_I + \beta_C + \gamma_i + d_k + p_l + \varepsilon$$

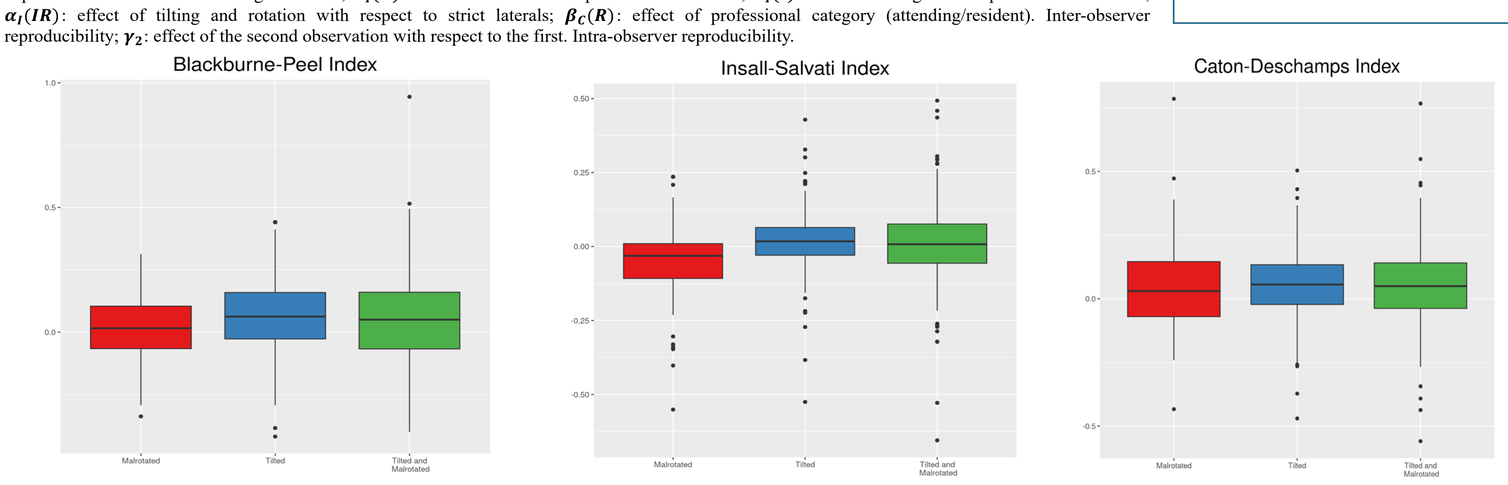
Statistical analyses were conducted using the R program, with statistical significance set at p<0.05.

RESULTS

In the **BPI**, statistically significant differences exist between strictly lateral radiographs and all those with some degree of tilting (up to 0.0937 and 0.0696). In the **ISI**, malrotation understimate the ISI up to 0.0757. **CDI** is affected by tilting (up to 0.0813), malrotation (up to 0.0728) and both combined (up to 0.0665). Good inter-observer reproducibility is obtained in all three PHI. Good intra-observer reproducibility is achieved in BPI and ISI, but not in CDI.

effect	coefficient (se)	CI95%	P
σ_P	0.1286	(0.1006; 0.1658)	
σ_d	0.0274	(0.0142; 0.0481)	
σ	0.1091	(0.1043; 0.1138)	
μ	0.8435 (0.0271)	(0.7909; 0.8961)	<.001
$\alpha_I(R)$	0.0136 (0.0156)	(-0.0169; 0.0442)	0.383
$\alpha_I(I)$	0.0686 (0.0128)	(0.0436; 0.0937)	<.001
$\alpha_I(IR)$	0.0519 (0.0090)	(0.0341; 0.0696)	<.001
$\beta_C(R)$	0.0024 (0.0205)	(-0.0398; 0.0446)	0.911
γ_2	0.0125 (0.0067)	(-0.0006; 0.0257)	0.062

Table 1. Linear mixed-effects model for the **BPI.** Variables: σ_p: patients variability; σ_d: physicians variability; σ: variability of the random effects; μ: expected value of the index being evaluated; $\alpha_I(R)$: rotation effect with respect to strict laterals; $\alpha_I(I)$: effect of tilting with respect to strict laterals; $\alpha_I(IR)$: effect of tilting and rotation with respect to strict laterals; $\beta_C(R)$: effect of professional category (attending/resident). Inter-observer reproducibility; γ_2: effect of the second observation with respect to the first. Intra-observer reproducibility.



Graphs 1-3 respectively. Box plot of the differences between strict lateral radiograph (p50 = 0.0) and rotated, tilted or both combined in each PHI

ABSTRACT

Background

Patella alta stands as a significant predisposing factor for patellofemoral instability. Utilized as a diagnostic tool, patellar heights indexes (PHI) require precise lateral knee radiographic projections for accurate computation. However, within clinical contexts, a notable proportion of radiographic images are taken with certain degrees of malrotation and/or tilting.

The primary aim of this investigation is to assess the impact of suboptimal radiographic positioning on the determination of patellar height, utilizing the Blackburne-Peel (BPI), Caton- Deschamps (CDI) and Insall-Salvati (ISI) indexes. Secondarily, it is evaluated whether it affects an index more than others and the inter-observer and intra-observer reproducibility.

Material and methods

Thirty-three patients with strictly lateral radiographs and one demonstrating some degree of tilt and/or rotation were included in the study. Four orthopedic surgeons specialized in knee surgery and four orthopedic surgery and traumatology residents conducted measurements on each radiograph in a randomized sequence at two different time points. A linear mixed-effects model was applied, with the quality of the radiograph (adequate projection vs. malrotation, tilt, or both), observer expertise (consultant or resident), and observation time regarded as fixed effects, while physician and patient were treated as random effects.

Results

Statistically significant differences were obtained between strict lateral and tilted radiographs in the BPI; between strict lateral and malrotated radiographs in the ISI and between tilted and/or rotated radiographs in the CDI. No significant differences were observed between resident observers and consultants in any of the indexes. Good inter-observer consistency was observed.

Conclusions

This study shows statistically significant differences in the determination of the three PHIs. Although these differences are small, they may predispose to diagnostic errors and inaccurate surgical planning in cases requiring surgical correction. Future studies quantifying the degrees of malrotation and/or inclination may further clarify these findings.

effect	coefficient (se)	CI95%	P
σ_P	0.1677	(0.1326; 0.2172)	
σ_d	0.1031	(0.0595; 0.1661)	
σ	0.0961	(0.0919; 0.1002)	
μ	1.2359 (0.0595)	(1.1207; 1.3512)	<.001
$\alpha_I(R)$	-0.0487 (0.0138)	(-0.0757; -0.0216)	<.001
$\alpha_I(I)$	0.0143 (0.0113)	(-0.0078; 0.0364)	0.206
$\alpha_I(IR)$	0.0103 (0.0080)	(-0.0053; 0.0260)	0.196
$\beta_C(R)$	-0.0067 (0.0731)	(-0.1518; 0.1384)	0.930
γ_2	0.0007 (0.0059)	(-0.0109; 0.0123)	0.902

Table 2. Linear mixed-effects model for the **ISI**

effect	coefficient (se)	CI95%	P
σ_P	0.1405	(0.1100; 0.1808)	
σ_d	0.0266	(0.0137; 0.0470)	
σ	0.1087	(0.1040; 0.1134)	
μ	0.9478 (0.0286)	(0.8921; 1.0035)	<.001
$\alpha_I(R)$	0.0423 (0.0156)	(0.0118; 0.0728)	0.007
$\alpha_I(I)$	0.0562 (0.0127)	(0.0314; 0.0813)	<.001
$\alpha_I(IR)$	0.0489 (0.0090)	(0.0311; 0.0665)	<.001
$\beta_C(R)$	0.0099 (0.0200)	(-0.0313; 0.0510)	0.639
γ_2	0.0166 (0.0067)	(0.0035; 0.0297)	0.013

Table 3. Linear mixed-effects model for the **CDI**

CONCLUSIONS

Our research emphasizes the significance of proper radiographic projection for assessing patellar height using the three indexes. While the deviations are minimal, they have the potential to result in errors in diagnosis or surgical planning. Tilting primarily impacts the BPI, ISI is affected by rotation and the CDI is affected by both rotation and tilting.

Future studies, incorporating a larger cohort and precise quantification of the degrees of malrotation and/or tilting, could provide further insight into these observations.

REFERENCES

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