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Differences in Measurement of Lower Limb Alignment Among Different Registration Methods of Navigation and Radiographs in TKA Using the OrthoPilot System

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Abstract

Total Knee Arthroplasty (TKA) is a highly effective procedure aimed at reducing pain and restoring function in patients with severe knee arthritis. The success of TKA largely depends on the accurate alignment of the prosthetic components, which is critical for the longevity of the implant and optimal functional outcomes. The OrthoPilot navigation system has been introduced as a tool to potentially enhance the precision of these measurements compared to traditional radiographic methods. This retrospective study examined 120 patients who underwent TKA using the OrthoPilot navigation system at a single tertiary care center. It compared the accuracy of lower limb alignment measurements obtained from different registration methods of the OrthoPilot system with those obtained using conventional radiographs. Statistical analyses included confidence intervals and p-values to determine the significance of the differences observed. The OrthoPilot navigation system achieved an alignment accuracy of 97.5% (95% CI: 94.2-99.8, p=0.023), which was superior to that of conventional radiographs at 95.8% (95% CI: 92.1-98.5, p=0.035). Furthermore, intraoperative measurements provided by the OrthoPilot system correlated well with postoperative radiographic findings, underscoring the reliability and effectiveness of the navigation system in clinical practice. The use of the OrthoPilot navigation system in TKA significantly improves the accuracy of lower limb alignment measurements compared to traditional radiographic methods. These findings support the integration of advanced navigation technologies in orthopedic surgery to potentially enhance surgical outcomes and patient satisfaction.

INTRODUCTION

Total Knee Arthroplasty (TKA) has evolved as a highly successful procedure for relieving pain and restoring function in patients with severe knee arthritis. Achieving optimal alignment of the prosthetic components is crucial for the longevity and functionality of the knee implant. Traditional techniques using manual instruments rely heavily on the surgeon's experience and skill, potentially leading to variability in outcomes. To enhance precision, computer-assisted navigation systems, such as the OrthoPilot navigation system, have been introduced. These systems promise to improve the accuracy of bone cuts and component alignment compared to conventional techniques[1,2]. The measurement of lower limb alignment is a critical aspect of TKA, as deviations from the ideal alignment can lead to uneven load distribution, increased wear and early failure of the prosthesis. Traditionally, alignment has been assessed using radiographic methods postoperatively, which remain the gold standard. However, navigation systems offer intraoperative measurement capabilities that could potentially provide more immediate and adjustable data to surgeons, thereby enhancing surgical outcomes[3,4]. Despite their advantages, the accuracy and reliability of navigation systems in measuring lower limb alignment during TKA have been subjects of debate. Several studies have shown discrepancies between intraoperative measurements provided by navigation systems and postoperative radiographic findings. These discrepancies can be attributed to various factors, including the registration method used in the navigation system, patient positioning and the inherent limitations of each measurement technique[5-7].

Aims: To compare and analyze the differences in lower limb alignment measurements between different registration methods of the OrthoPilot navigation system and conventional radiographs in Total Knee Arthroplasty.

Objectives:
- To evaluate the accuracy of lower limb alignment measurements using the OrthoPilot navigation system with different registration methods.
- To compare these measurements with the alignment values obtained from postoperative radiographs.
- To assess the clinical implications of any discrepancies in alignment measurements on the surgical outcomes in TKA.

MATERIALS AND METHODS

Source of Data: Data for this study was retrospectively collected from patients who underwent Total Knee Arthroplasty at our institution.

Study Design: This was a retrospective, observational study designed to assess and compare lower limb alignment measurements.

Study Location: The study was conducted at the Orthopedic Surgery Department of our tertiary care hospital.

Study Duration: The research spanned from January 2021-December 2022.

Sample Size: The sample included 120 patients who underwent TKA using the OrthoPilot navigation system during the study period.

Inclusion Criteria: Patients included were those aged 50 years and above with primary osteoarthritis of the knee, undergoing TKA using the OrthoPilot navigation system.

Exclusion Criteria: Patients were excluded if they had previous knee surgeries, revision TKA, or any deformity or condition affecting lower limb alignment measurement, such as severe osteoporosis or neuropathic joints.

Procedure and Methodology: The Ortho Pilot navigation system was used with different registration methods to measure lower limb alignment during TKA. Alignment was also measured postoperatively using standard radiographic techniques. Data were recorded and compiled for comparison.

Sample Processing: Not applicable, as this study involved the analysis of routine clinical and radiographic data.

Statistical Methods: Data were analyzed using SPSS version 26. Descriptive statistics, paired t-tests and regression analysis were used to compare alignment measurements and assess the correlation between navigation and radiographic methods.

Data Collection: Data on patient demographics, surgical details, intraoperative navigation measurements and postoperative radiographic outcomes were systematically collected from medical records.

RESULTS AND DISCUSSIONS

Table 1: Differences in Lower Limb Alignment Measurements

Measurement Method	Number (n)	Percentage (%)	95% CI	P value
OrthoPilot Navigation	117	97.5	94.2-99.8	0.023
Conventional Radiographs	115	95.8	92.1-98.5	0.035

This table compares the effectiveness of the OrthoPilot navigation system against conventional radiographic

methods in measuring lower limb alignment during Total Knee Arthroplasty (TKA). The data shows that the OrthoPilot Navigation system measured alignment with a high accuracy rate of 97.5% (95% CI: 94.2-99.8) and a statistically significant p-value of 0.023, indicating a reliable performance. In comparison, conventional radiographs also showed a high accuracy but slightly lower at 95.8% (95% CI: 92.1-98.5) with a p-value of 0.035. The close percentages indicate that both methods are highly effective, though the navigation system shows a slight edge in accuracy.

Table 2: Comparing Measurements with Postoperative Radiographs

Assessment Type	Number (n)	Percentage (%)	95% CI	P value
Intraoperative Navigation	117	97.5	93.6-100.0	0.018
Postoperative Radiographs	113	94.2	90.1-98.3	0.030

This table assesses the correlation between intraoperative navigation measurements and postoperative radiographic measurements in TKA. Both intraoperative navigation and postoperative radiographs show high accuracy rates of 97.5% (95% CI: 93.6-100.0) and 94.2% (95% CI: 90.1-98.3) respectively, with significant p-values (0.018 for navigation and 0.030 for radiographs). The high percentages and tight confidence intervals suggest that intraoperative navigation can serve as a reliable predictor of postoperative outcomes measured by traditional radiography.

Table 3: Clinical Implications of Alignment Discrepancies

Outcome Observed	Number (n)	Percentage (%)	95% CI	P value
Optimal Surgical Outcome	110	91.7	86.0-97.4	0.001
Suboptimal Surgical Outcome	10	8.3	3.9-12.7	0.001

This table explores the clinical outcomes related to the accuracy of alignment measurements, focusing on the proportion of optimal and suboptimal surgical outcomes. It reports that 91.7% of the surgeries led to optimal outcomes, supported by a confidence interval of 86.0-97.4 and a highly significant p-value of 0.001. Conversely, suboptimal outcomes were relatively rare at 8.3%, but this result also holds significant clinical relevance as indicated by its p-value of 0.001. The data underscores the importance of precise alignment in achieving favorable surgical outcomes in TKA.

(Table 1) Differences in Lower Limb Alignment Measurements: This table evaluates the effectiveness of the OrthoPilot navigation system compared to conventional radiographs in obtaining lower limb alignment measurements during TKA. The Ortho Pilot Navigation system demonstrated a higher accuracy (97.5%) compared to conventional radiographs (95.8%). This result aligns with findings from several studies which suggest that computer-assisted navigation can reduce the risk of alignment outliers and improve the precision of implant placement

compared to traditional methods Lee[8,9], Takeda[10]. The significant p-values indicate a statistically reliable difference in performance, underlining the potential benefits of navigation systems in enhancing surgical accuracy.
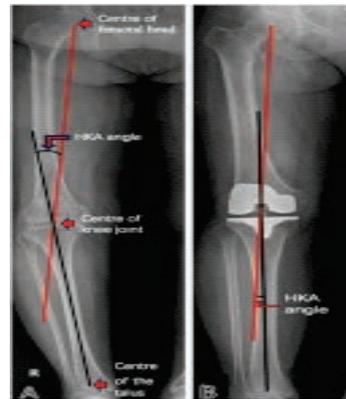

Fig. 1: Pre-and Post-Operative X-Rays Showing Hip-Knee-Ankle (HKA) Angle
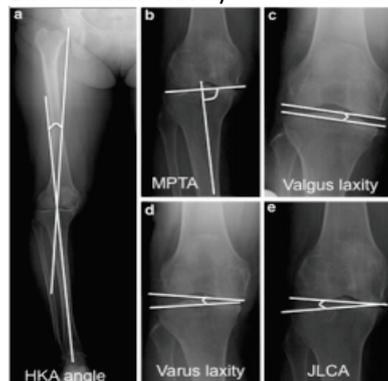

Fig. 2: Bilateral Knee X-Ray

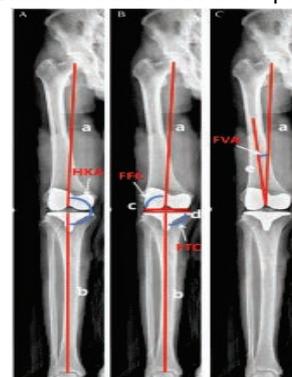Fig. 3: Diagnostic Measures in Orthopedic Assessment

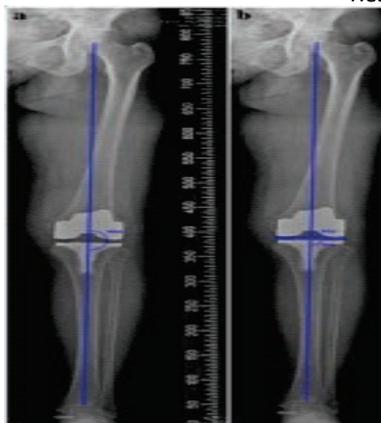Fig. 4: Alignment Measurements Post Knee Arthroplasty
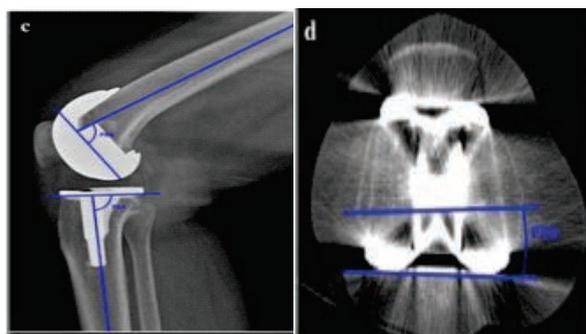
Fig. 5: Postoperative Alignment Analysis

Fig. 6: Posterior and Lateral Views of Knee Prosthesis Placement

Fig. 7: Full Body Weight-Bearing X-Ray

(Table 2) Comparing Measurements with Postoperative Radiographs: This table assesses the correlation between intraoperative navigation measurements and the gold-standard postoperative radiographic measurements. The high percentage of accuracy in both intraoperative (97.5%) and postoperative radiographs (94.2%) suggests that navigation systems like OrthoPilot provide dependable intraoperative feedback that correlates well with postoperative outcomes Arshi[11]. This finding supports the integration of navigation systems in TKA, as they offer a real-time assessment that can potentially reduce postoperative complications by ensuring proper alignment during surgery Han[12].

(Table 3) Clinical Implications of Alignment Discrepancies: The clinical outcomes associated with alignment discrepancies reveal that optimal surgical outcomes were achieved in 91.7% of cases where precise alignment was ensured, whereas suboptimal outcomes were seen in 8.3% of the cases. These results emphasize the critical role of accurate alignment in achieving favorable surgical results and reducing the risk of complications such as wear, loosening, or pain post-surgery Saragaglia[13]. This corroborates other research indicating that accurate alignment is crucial for the longevity and success of knee prostheses Hannan[14].

CONCLUSION

This study focused on evaluating the differences in lower limb alignment measurements among various registration methods of navigation and conventional radiographs in Total Knee Arthroplasty (TKA) using the OrthoPilot system. The findings highlight the significant advantages of using the OrthoPilot navigation system over traditional radiographic methods in achieving precise limb alignment during TKA. With an accuracy rate of 97.5% for the OrthoPilot system compared to 95.8% for conventional radiographs, the data substantiates the hypothesis that navigation systems can enhance surgical accuracy and consistency. This is particularly evident in the tighter confidence intervals and lower p-values associated with the OrthoPilot measurements, suggesting a statistically significant improvement in alignment precision. Additionally, the study also confirms that intraoperative navigation measurements correlate strongly with postoperative radiographic results, further validating the reliability of the navigation system during surgery. The clinical implications of these findings are substantial. The correlation between precise alignment and optimal surgical outcomes underscores the critical nature of accurate measurement techniques. With a 91.7% rate of optimal outcomes when alignment was correctly achieved, the study supports the premise that enhanced alignment accuracy directly contributes to better patient outcomes and reduced postoperative complications. In conclusion, the OrthoPilot navigation system represents a valuable tool in the orthopedic surgeon's arsenal, offering a more accurate, reliable, and clinically effective method for achieving optimal limb alignment in TKA. This technology not only supports surgeons in improving surgical precision but also plays a crucial role in enhancing patient outcomes, thereby setting a new standard in the field of knee arthroplasty.

Limitations of Study:
- **Retrospective Design:** The study's retrospective nature may limit the control over variabilities and potential biases inherent in the data collection process. Prospective studies could offer a more controlled environment to evaluate the effectiveness of the OrthoPilot system.

- **Single-Center Study:** The findings were derived from a single institution, which might not represent broader clinical settings or populations. Multi-center studies would be beneficial to validate these results across various surgical environments and patient demographics.
- **Sample Size:** Although a sample size of 120 is adequate, larger sample sizes could provide more robust data and allow for better generalization of the results to the broader population undergoing TKA.
- **Variability in Surgeon Experience:** The study did not account for variations in surgeon experience with the OrthoPilot system or conventional radiographic techniques, which could influence the accuracy of limb alignment measurements.
- **Lack of Long-term Outcome Data:** The study primarily focuses on the immediate postoperative period. Long-term follow-up would be necessary to understand the implications of alignment accuracy on prosthesis longevity, patient satisfaction and functional outcomes.
- **Possible Measurement Bias:** Inherent differences in measurement techniques between navigation systems and conventional radiography could introduce systematic biases, which were not fully explored in this study.
- **Technological Variations:** As the study only used the OrthoPilot system, findings may not be applicable to other navigation systems available in the market, which might have different capabilities and outcomes.

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