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Anatomy

Morphometric analysis of anatomical reference points in hip surgery: A study on cadaveric and radiographic images

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ABSTRACT

Objectives: This study aims to evaluate the accuracy of morphometric measurements obtained from cadavers and anteroposterior (AP) pelvic radiographs.

Methods: A total of 15 cadavers from the anatomical collection of Cukurova University and 217 AP pelvic radiographs from individuals aged 65-80 years with no orthopedic conditions were analyzed. Morphometric measurements were taken from cadavers using Kirschner wires placed at anatomical reference points: the spina iliaca anterior superior (SIAS), the highest point of the crista iliaca (CI), and the trochanter major (TM). Distances were measured with a non-elastic tape, and angular measurements were conducted using ImageJ software. These were compared with radiographic data analyzed via the PACS system. Statistical analysis was performed using SPSS 20 with One-Way ANOVA to assess group differences.

Results: The mean age was 70.98±4.70 years for radiograph individuals and 80.36±5.13 years for cadavers. Significant differences were found between cadaveric, dissected cadaver, and radiological measurements. The SIAS-TM distance was longest in cadavers (113.82±7.46 mm) and shortest in radiographs (92.73±14.36 mm). The CI-TM distance was greatest in radiographs (147.81±12.02 mm), while the SIAS-CI distance was longest in cadavers (78.95±6.48 mm). Differences in SIAS-TM ($P<0.001$), CI-TM ($P=0.007$), and SIAS-CI ($P=0.029$) distances were statistically significant. Angular measurements also varied, with radiographs showing higher SIAS angles and cadavers showing greater TM and CI angles, especially on the right side.

Conclusions: The study reveals notable discrepancies between cadaveric and radiological morphometric measurements. These cadaver-based findings may serve as valuable resources for surgical training and anatomical education, especially in hip arthroplasty planning.

Keywords: Arthroplasty, cadaver, hip, morphometry, radiography

Total hip arthroplasty (THA) is a significant surgical procedure performed to improve joint stability, mobility, gait function, and overall quality of life. In orthopedic practice, femoral neck fractures and hip prosthesis applications are commonly addressed using various techniques, including the anterolateral approach. In recent years, the use of minimally invasive techniques in THA has led to no-

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table improvements in surgical outcomes. Nevertheless, standard surgical approaches remain widely used and continue to yield generally favorable results [1]. The preference for minimally invasive techniques accelerates the recovery process and enhances soft tissue healing in various surgical procedures such as cholecystectomy, meniscectomy, and anterior cruciate ligament reconstruction. These positive developments have also made an impact in hip surgery and are increasingly being adopted in total hip arthroplasty procedures. Studies in the literature emphasize that minimally invasive techniques are associated with fewer complications and faster recovery processes [2-4]. However, interindividual anatomical variations and the technical diversity of orthopedic surgery make it important to accurately determine the distances between anatomical reference points during surgical planning. Aligning incision lines determined through clinical experience with precise anatomical measurements may enhance both the accuracy and safety of surgical procedures. Moreover, well-positioned and minimally sized incisions can accelerate recovery, reduce postoperative pain, and help patients regain functional mobility and return to daily life more quickly. Accordingly, the study sought to answer the following key questions: What is the degree of similarity between morphometric measurements obtained using Kirschner wires on cadavers and anthropometric data derived from anteroposterior (AP) pelvic radiographs? To what extent do the distances between anatomical reference points identified on radiological images correspond with the incision lines subjectively determined by orthopedic surgeons on cadavers? Furthermore, can morphometric measurements performed on cadavers, when compared with AP pelvic radiographic data, lead to more precise and safer approaches in surgical practice? Based on these questions, the study was designed around the following hypotheses:

(1) There is a significant difference between Kirschner wire measurements performed on cadavers and anthropometric measurements obtained from AP pelvic radiographs.

(2) Kirschner wire measurements made on cadavers are similar to measurements obtained after dissection.

Morphometric analyses in the literature are mostly based on computed tomography (CT) images [5, 6] and dry bone models [7, 8]. However, these methods have limitations in reflecting soft tissue relationships, which may reduce their clinical applicability. Furthermore, many cadaver-based morphometric studies in the literature primarily focus on the proximal femur, particularly the femoral head, neck, and trochanteric region which are directly involved in prosthesis placement [9, 10]. However, effective surgical incision planning also requires precise knowledge of the upper anatomical boundaries of the pelvis, including palpable and clinically relevant landmarks such as the spina iliaca anterior superior (SIAS), the highest point of the crista iliaca (CI), and the trochanter major (TM).

Despite their importance, cadaveric measurements involving these pelvic landmarks remain limited in the current literature. This study aims to address this gap by providing a comparative analysis of morphometric data obtained from both cadavers and anteroposterior pelvic radiographs, focusing specifically on these anatomical reference points. In doing so, the study not only contributes to the academic body of knowledge but also supports the development of safer and more reliable incision strategies in surgical practice. Moreover, another aim of this study is to contribute to surgical training programs focused on hip arthroplasty by providing detailed cadaveric measurements and anatomical images of the pelvic region. Cadaver-based training plays a critical role in enhancing surgeons' confidence and offering a safe environment for practicing complex surgical procedures [11-13]. These materials, which reflect real tissue characteristics, help reinforce anatomical knowledge and improve technical skills, thereby facilitating a more effective transition from theoretical education to clinical practice.

In this context, our study aimed to evaluate morphometric measurements performed on cadavers in conjunction with radiological image analysis, to contribute to the development of anatomical standards that can be applied in clinical practice. Moreover, by providing measurable data that can support minimally invasive hip prosthesis approaches, this research lays a foundation for the refinement of surgical techniques.

METHODS

Study Population

In this study, 15 cadavers from the anatomical collection of the Department of Anatomy, Faculty of Medicine, Cukurova University, and 217 anteroposterior (AP) pelvic radiographs were analyzed. Both the cadavers and the radiographic images belonged to individuals aged between 65 and 80 years. To minimize the confounding effect of age, we specifically selected radiographic images from individuals in the same age range as the cadavers (average age of cadavers: 80.36±5.13 years; radiograph group: 70.98±4.70 years). This approach ensured age homogeneity across groups, thereby eliminating the need for stratified analysis by age decades. This methodological decision was made to focus the analysis on anatomical and measurement technique differences, rather than demographic variability. The selected individuals had no history of orthopedic diagnosis or surgical intervention involving the lower extremities. Radiological data were obtained from the archives of the Department of Orthopedics and Traumatology at Faculty of Medicine, Cukurova University, following the necessary institutional approvals. Ethical approval for the use of cadavers was granted by the relevant institutional authorities, and the entire study was approved by the Non-Invasive Clinical Research Ethics Committee of Cukurova University Faculty of Medicine on November 8, 2024 (Decision No: 149/7). All experimental procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Study Design

This study aims to determine the morphometric values of anatomical reference points important for hip arthroplasty. To enhance the clarity and reproducibility of the methodology, a structured summary of the step-by-step measurement protocol is presented in Table 1. This protocol encompasses both cadaveric and radiographic procedures, including details on subject preparation, anatomical reference point identification, measurement techniques, and the comparison of collected data. Cadaveric measurements involving the use of Kirschner wires were performed by a professor of

Table 1. Summary of morphometric measurement protocol

Step	Procedure	Details
Study objective	Determination of anatomical distances and comparison of measurement methods	Focus on SIAS, CI, and TM points relevant for hip arthroplasty
Cadaver preparation and marking	Identification and marking of reference points on cadavers (Figs. 1 and 2)	Kirschner wires placed by an orthopedic surgeon at SIAS, CI, and TM according to the hip incision line
Cadaveric measurements	Measurement of distances on cadavers (Figs. 1 and 2)	Non-elastic tape used to measure: - SIAS-TM - CI-TM - SIAS-CI Performed before and after dissection
Radiographic image acquisition	Retrieval and standardization of AP pelvic radiographs	- Supine patient positioning - Neutral lower limb alignment - 100 cm source-to-image distance (SID) - Radiopaque calibration marker placed at TM level
Radiographic measurements	Digital measurement on radiographs	DICOM images analyzed using PACS system tools; same anatomical points measured digitally
Data comparison	Cross-method analysis	Comparison of cadaveric and radiographic data to assess correlation, accuracy, and reproducibility

SIAS=spina iliaca anterior superior, TM=trochanter majör, CI=crista iliaca, PACS=Picture Archiving and Communication System, DICOM=Digital Imaging and Communication in Medicine

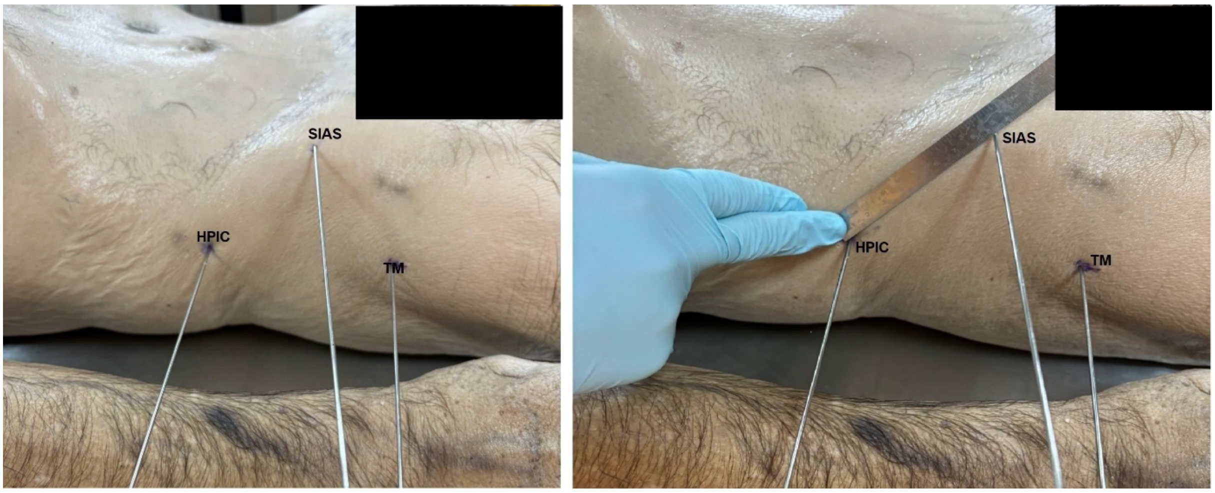

Fig. 1. Representation of the reference points (spina iliaca anaterior superior (SIAS), trochanter major (TM), and crista iliaca (CI)) and length measurements on cadaveric specimens.

orthopedics. The dissections of the cadavers were conducted by an experienced anatomist, who also carried out the post-dissection measurements as well as all radiographic measurements. As each type of measurement was performed by a single expert observer, interobserver reliability (e.g., Intraclass Correlation Coefficients) was not calculated. While this may limit the assessment of reproducibility across multiple raters, it ensures internal consistency by avoiding interobserver variability. Furthermore, the advanced qualifications and relevant expertise of both observers support the methodological reliability of the measurements.

Anatomical Reference Points and Measurements

In this study, the SIAS, the highest point of the CI, and the TM were identified as anatomical reference points. Length and angular measurements were conducted between these landmarks.

Cadaveric Morphometric Measurements

The distances between anatomical reference points were determined on cadavers using Kirschner wires placed by an orthopedic specialist. The wires were inserted by palpating the relevant anatomical landmarks - SIAS, the highest point of CI, and TM - with consideration of the planned incision line (Figs. 1 and 2). Following the placement of the wires, length measurements were performed between the reference points. In addition to these initial assessments, the same morphometric parameters were re-measured on the same cadavers after dissection, allowing for comparison between pre- and post-dissection values.

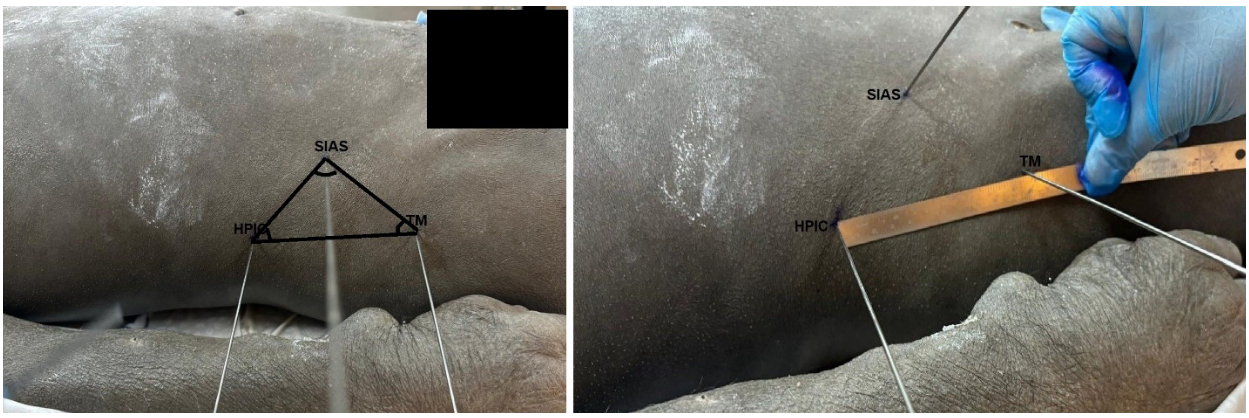

Fig. 2. Representation of the reference points (spina iliaca anterior superior [SIAS], trochanter major [TM], and crista iliaca [CI]) and angle measurements on cadaveric specimens.

Length Measurements

The distances between SIAS and TM, CI and TM, and SIAS and CI were measured using a non-elastic measuring tape to ensure consistency and accuracy (Fig. 1).

Angular Measurements

After transferring cadaveric images to a computer environment, angular measurements were digitally performed using ImageJ software (version 1.52a), which offers a precision of 1/100 mm. Using the angle measurement tool within the software, the distal point of the angle was first selected. A line was then drawn toward the vertex of the angle, followed by a second line extending to the third point, thus completing the angular configuration. The resulting angle values were recorded in degrees. This digital method enabled highly precise and repeatable angular assessments. Angular measurements were taken at the SIAS, CI, and TM points, as illustrated in Fig. 2.

Radiological Imaging and Morphometric Measurements

The same anatomical reference points - SIAS, the highest point of CI, and TM - were evaluated on anteroposterior (AP) pelvic radiographs using anthropometric measurements (Fig. 3). Radiographic images were acquired with patients in a supine position, with the lower limbs positioned neutrally and parallel to avoid rotation artifacts. A standard source-to-image distance (SID) of 100 cm was used during image acquisition, consistent with conventional pelvic radiography protocols. To ensure measurement accuracy, a radiopaque calibration marker (metallic ball of known diameter) was included at the level of the greater trochanter in each image field. This reference object allowed proper scaling and adjustment of digital measurements. Morphometric distances between SIAS and TM, CI and TM, and SIAS and CI were digitally measured using radiographic imaging software. Patient radiographs were retrieved from the Mergentech

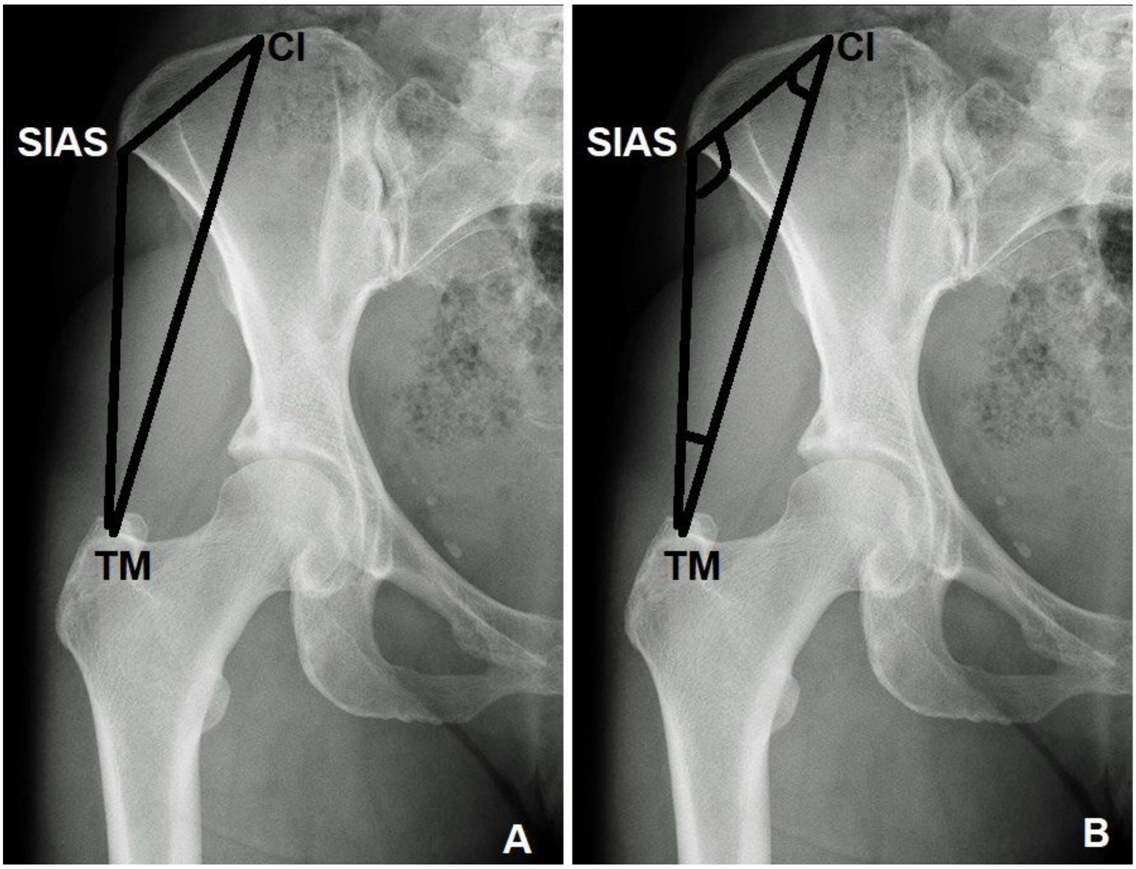

Fig. 3. Radiological representation of the reference points (spina iliaca anaterior superior [SIAS], trochanter major [TM], and crista iliaca [CI]) along with length and angle measurements

Hospital Information Management System (HIMS) and analyzed via the PACS (Picture Archiving and Communication System). All measurements were performed directly within the PACS environment on DICOM (Digital Imaging and Communication in Medicine)-format images, using its built-in measurement tools. PACS ensured high reliability and reproducibility through secure data handling, image fidelity, and measurement standardization. Morphometric data obtained from Kirschner wire placements on cadavers were compared with the corresponding radiological measurements to assess correlation and structural consistency between both methods. The imaging protocol and digital analysis tools used in this study are consistent with current best practices reported in radiologic morphometry literature.

Statistical Analysis

In our study, statistical analysis was performed on the morphometric data obtained from cadaveric and radiological images. Using SPSS version 20.0, the Descriptive Statistics function was utilized to calculate the mean and standard deviation of the morphometric parameters.

Prior to the application of parametric tests, the distribution of the data was evaluated using the Shapiro-Wilk test. The results indicated that the data were normally distributed across all measurement variables (e.g., SIAS–TM, CI–TM, SIAS–CI). For example, the Shapiro–Wilk test yielded the following P-values: (1) SIAS-TM (cadaveric) (P=0.421); (2) CI-TM (cadaveric) (P=0.386); (3) SIAS-CI (cadaveric) (P=0.537); (4) SIAS-TM (radiographic) (P=0.452); (5) CI-TM (radiographic) (P=0.496); and (6) SIAS-CI (radiographic) (P=0.478). As all P-values were greater than 0.05, the assumption of normality was met. Therefore, a One-Way Analysis of Variance (ANOVA) was conducted to compare the morphometric values between cadaveric and radiological measurements. This analysis revealed whether the differences between the two imaging modalities were statistically significant. Given the normal distribution of the data and fulfillment of test assumptions, the use of ANOVA was considered statistically valid and reliable.

RESULTS

A total of 15 cadavers (30 lower extremities; 11 males, 3 females) and 217 AP pelvic radiographs (434 lower extremities; 97 males, 120 females) were evaluated. The mean age of radiographic cases was 70.98±4.70 years, while cadavers averaged 80.36±5.13 years.

Morphometric comparisons revealed statistically significant differences across cadaveric, dissected cadaveric, and radiographic groups (Table 2) (Fig. 4). Notably, the SIAS-TM distance showed a progressive decrease from cadavers to radiographic images (F=31.66, P<0.001), with cadavers exhibiting the highest values and radiographs the lowest. Conversely, the CI-TM distance was longest in radiographs (F=5.40, P=0.007). The SIAS-CI distance was shortest

Table 2. The comparison of measurements taken with the Kischner wire on cadavers, measurements taken after dissection, and measurements made on AP pelvic images according to side

Parameters (mm)	Cadavers (n=15)	Total (n=30)	Dissected cadavers (n=15)	Total (n=30)	AP pelvic images (n=217)	Total (n=434)
SIAS-TM (R)	114.00±5.51	113.82±7.46	104.20±4.92	104.17±6.59	93.79±14.76	92.73±14.36
SIAS-TM (L)	113.63±9.29		104.13±8.11		91.59±13.88	
CI-TM (R)	137.64±6.27	136.05±7.16	138.80±6.06	137.43±6.84	147.04±12.47	147.81±12.02
CI-TM (L)	134.46±7.92		136.07±7.51		148.62±11.51	
SIAS-CI (R)	78.00±8.12	78.95±6.48	79.80±7.91	80.13±6.49	70.05±11.28	71.93±12.22
SIAS-CI (L)	79.91±4.50		80.53±4.84		73.91±12.86	

Data are shown as mean±standard deviation. SIAS=spina iliaca anterior superior, TM=trochanter major, CI=crista iliaca, R=right, L=left, mm=millimeter, AP= anteroposterior

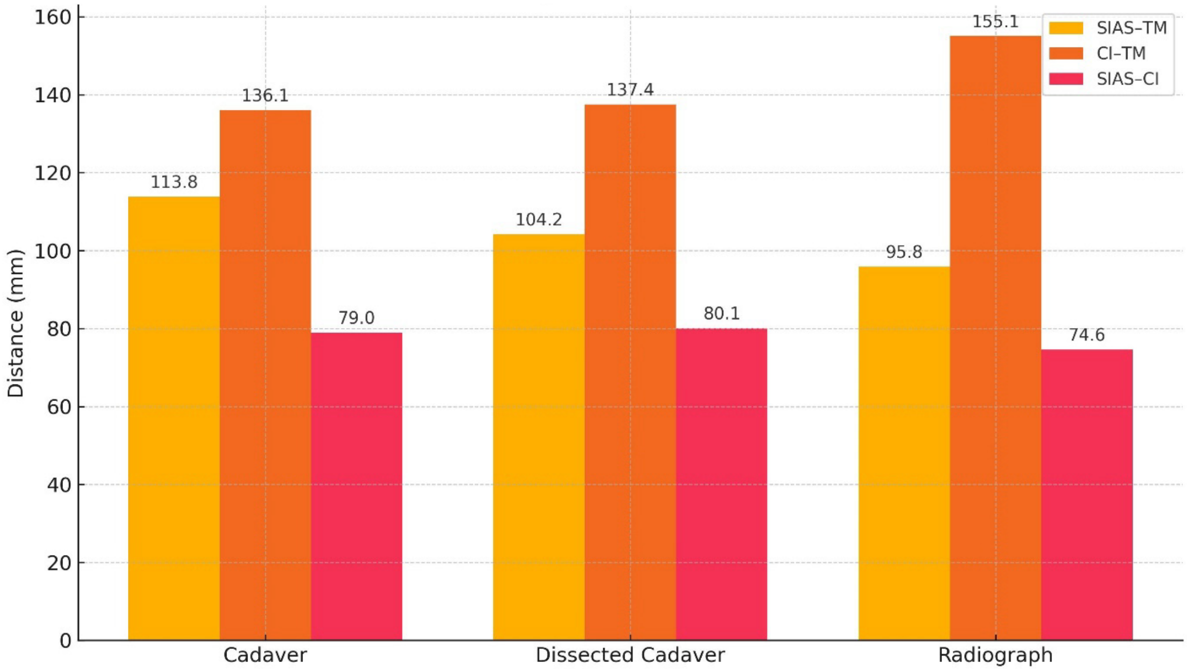

Fig. 4. **Comparison of morphometric distances by metod**

in radiographs and differed significantly between groups (F=3.76, P=0.029). These findings suggest that radiographic imaging may systematically alter linear measurements due to soft tissue compression or projection variability.

Laterality analysis revealed consistent patterns across all three groups. In cadaveric and dissected cadaveric specimens, the right-side measurements (e.g., SIAS-TM and CI-TM) were generally longer than the left, whereas in radiographic images, the difference between right and left was less pronounced and did not reach statistical significance. Interestingly, the SIAS-CI distance was consistently longer on the left side in all three groups, and this asymmetry was statistically significant. Moreover, angular evaluations at SIAS, TM, and CI landmarks also exhibited methodological variation. Radiographs yielded higher angular values at the SIAS, while TM and CI angles tended to be greater in cadaveric measurements, especially on the right side (Table 3, 4) (Fig. 5). These angular differences underline the influence of measurement modality on anatomical interpretation and may have clinical implications for surgical planning. When comparing the two methods, it was observed that radiological measurements tended to yield slightly higher angular values at the SIAS, whereas cadaveric measurements presented greater values at the TM and CI points, particularly on the right side. Moreover, Fig. 6

Table 3. Similarity between measurements marked with kischner wire, measurements taken post-dissection, and radiographic measurements

Parameters (mm)	Cadavers (n=30)	Dissected cadavers (n=30)	AP pelvic images (n=434)	F	P value
SIAS-TM	113.82±7.46	104.16±6.58	95.83±14.66	31.66	**<0.001**
CI-TM	136.05±7.16	137.43±6.84	155.13±13.89	5.40	**0.007**
SIAS-CI	78.95±6.48	80.13±6.48	74.58±12.34	3.76	**0.029**

Data are shown as mean±standard deviation. SIAS=spina iliaca anterior superior, TM=trochanter major, CI=crista iliaca, mm=millimeter, AP= anteroposterior

F=between-group variance; P=significance level (One-Way ANOVA)

Table 4. The angles at the measurement locations in cadavers and AP pelvic images

Parameters (mm)	Cadavers (n=15)	Total (n=30)	AP pelvic images (n=217)	Total (n=434)
SIAS (R)	121.27±9.13	119.04±7.46	130.38±4.58	126.53±6.20
SIAS (L)	116.43±4.28		120.77±1.07	
CI (R)	31.44±5.46	32.51±4.53	27.88±6.22	30.42±5.61
CI (L)	33.75±3.14		34.24±0.08	
TM (R)	28.77±4.70	28.47±3.88	24.70±2.03	25.80±2.58
TM (L)	28.12±3.06		27.45±3.04	

Data are shown as mean±standard deviation. SIAS=spina iliaca anterior superior, TM=trochanter major, CI=crista iliaca, R=right, L=left, mm=millimeter, AP= anteroposterior

presents 3D scatter plots illustrating the relationship among three key anatomical distances (CI-TM, SIAS-CI, and SIAS-TM) in radiological (A) and cadaveric (B) datasets. In the radiological group (A), data points are densely clustered and form a relatively linear distribution, indicating strong internal consistency and positive correlation among the three measured distances across a larger sample size. In contrast, the cadaveric group (B) displays a more dispersed and less densely packed pattern, reflecting greater interindividual variability likely due to anatomical diversity, postmortem changes, and lower sample size. Notably, while overall trends are preserved in both datasets, the cadaveric values occupy a relatively narrower CI-TM range and a higher SIAS-CI span, suggesting modality-specific influences on spatial relationships between anatomical landmarks.

DISCUSSION

The primary aim of this study is to contribute to the establishment of surgical standards by evaluating key anatomical reference points relevant to the incision line used in the minimally invasive anterolateral approach, through morphometric measurements per-

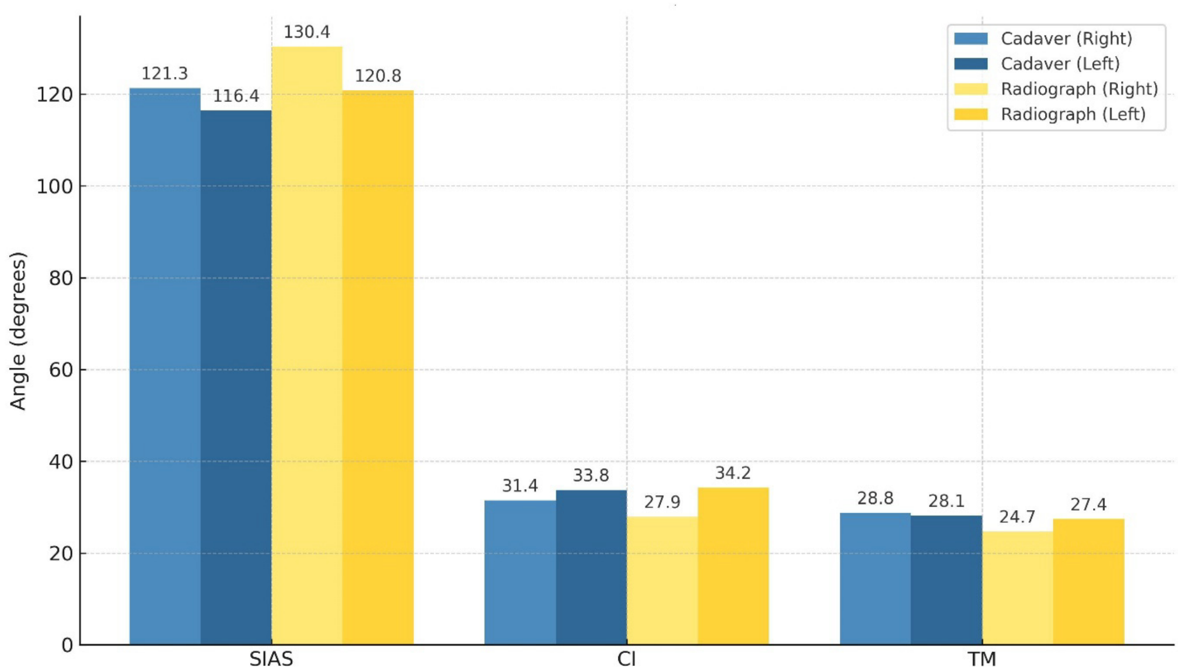

Fig. 5. **Comparison of angular measurements by metod and side**

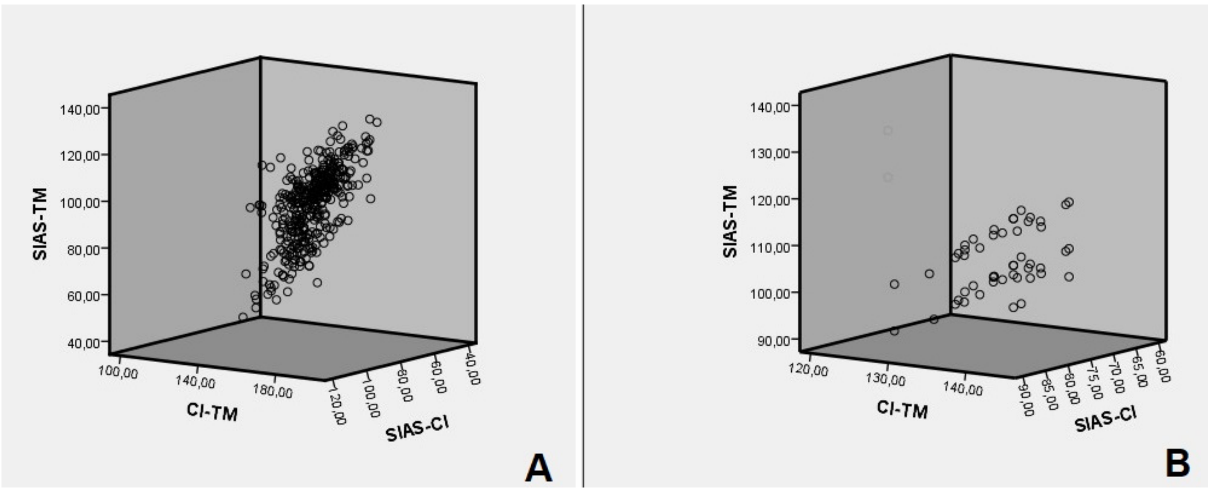

Fig. 6. **Distribution of length measurements compared between radiological measurements (A) and cadaveric specimens (B)**

formed on both cadavers and radiological images. In the literature, studies describing the minimally invasive anterolateral approach emphasize that the patient is positioned in the lateral decubitus position, and SIAS and TM are identified as critical anatomical landmarks. The incision is typically made approximately 10 cm in length, extending between the middle and posterior thirds of the line connecting these two points. In standard THA, the incision length typically ranges between 15 and 25 cm, whereas in minimally invasive techniques, this length is reduced to approximately 10 cm. This reduction in incision size highlights the importance of accurately identifying anatomical landmarks such as SIAS and TM to ensure both surgical efficacy and safety in limited surgical fields. Accordingly, our study focused on morphometric evaluation of the distances between these reference points on cadavers and anteroposterior pelvic radiographs, with the aim of providing objective data that can serve as reliable references in surgical practice.

The first hypothesis of this study stated that "there is a significant difference between Kirschner wire measurements performed on cadavers and anthropometric measurements obtained from AP pelvic radiographs." The findings of the study clearly support this hypothesis. Statistical analyses revealed significant differences among the cadaveric, dissected cadaver, and radiological measurements for the distances between SIAS-TM, CI-TM, and SIAS-CI ($P<0.05$; see Table 2 and Table 3). Notably, the SIAS-TM and SIAS-CI distances were consistently shorter in radiological measurements, which may be attributed to factors such as soft tissue compression, differences in positioning, and the limitations of two-dimensional imaging. These results confirm that the measurement method has a direct impact on the observed morphometric values, thereby validating the first hypothesis. The second hypothesis proposed that "Kirschner wire measurements made on cadavers are similar to measurements obtained after dissection." The results of this study also support this assumption. Comparisons between cadaveric and dissected cadaver data revealed no statistically significant differences for most of the morphometric parameters, and overall measurement trends were consistent. For instance, the CI-TM and SIAS-CI distances remained nearly identical before and after dissection, indicating that the dissection process did not substantially alter the spatial relationships of key anatomical landmarks. This finding is consistent with previous studies by Verma *et al*. [7] and Solomon *et al*. [8], which suggested that radiological images may underestimate anatomical distances, especially in complex regions like the hip. Such discrepancies highlight the potential limitations of relying solely on radiographic data for surgical planning, particularly in minimally invasive procedures. Therefore, cadaveric measurements, being more directly reflective of anatomical reality, are essential for ensuring precise surgical planning. On the other hand, other studies, such as those by Austin *et al*. [14], Vanrusselt *et al*. [15], Cantrell *et al*. [16], and Heinz *et al*. [17], have emphasized the importance of radiological evaluations, particularly in postoperative assessments. They argue that radiological morphometric measurements are crucial tools in evaluating the success of hip arthroplasty, providing vital insights into the positioning and alignment of the prosthesis post-surgery. Given these perspectives, it is clear that both cadaveric and radiological measurements offer valuable contributions to different stages of surgical planning and evaluation. Therefore, in our study, we integrated both types of measurements to ensure a comprehensive approach. By combining the accuracy of cadaveric measurements with the clinical relevance of radiological assessments, we aimed to provide a balanced and reliable framework for surgical planning, ensuring both precision in preoperative measurements and practical applicability in postoperative evaluations. This dual approach enhances the robustness of our findings and ensures that both anatomical accuracy and clinical feasibility are accounted for in the surgical process. Additionally, the study found differences in the side-to-side measurements, particularly in the SIAS-TM distance, where the right side was consistently longer in cadavers. In contrast, no significant side-to-side difference was found in radiological images. This mirrors findings from Sugano *et al*. [5], and Zhai *et al*. [6], who highlighted that anatomical asymmetries are common but often underrepresented in radiological imaging. This suggests that when planning surgeries, particularly in minimally invasive approaches, surgeons should account for potential anatomical variations between the sides, which may not be captured accurately in radiographs. Another noteworthy observation is the similarity between the measurements obtained from cadavers and dissected cadavers. The close alignment of these two measurement methods emphasizes the reliability of cadaveric measurements in surgical applications. As noted by Verma *et al*. [7], dissected cadavers provide an invaluable source of precise anatomical data that can be directly applied to surgical planning. This study further confirms that dissected cadavers are useful models for obtaining measurements with a high degree of accuracy, supporting their use in surgical training and preoperative planning.

Our study also revealed that the distances between anatomical points, such as the SIAS-TM and SIAS-CI, differed significantly between cadavers, dissected cadavers, and radiological images. Specifically, while the SIAS-TM and SIAS-CI distances were shorter in radiographs compared to cadaveric measurements, the CI-TM distance was longer in radiological images. This finding reinforces the importance of using accurate anatomical measurements when planning minimally invasive surgeries. Furthermore, angular measurements at anatomical landmarks such as the SIAS, TM, and CI showed significant differences between cadaveric and radiological measurements. In cadavers, the average angle at the SIAS was 121.27° on the right side, whereas in radiological assessments, the angle was 130.38°. These angular data provide more detailed information about the spatial configurations of bony structures, going beyond mere linear morphometric comparisons. Particularly in orthopedic surgical planning, applications such as implant placement, guidance of incision lines, and positioning of prosthetic components benefit from these angular measurements by providing surgeons with a more comprehensive anatomical insight. Moreover, identifying angular inconsistencies between different measurement methods (cadaveric vs. radiographic) allows for questioning which methods are more reliable in clinical practice. Also, including angular measurements alongside linear dimensions in this study contributed to a more holistic understanding of the three-dimensional relationships of anatomical structures and enabled strengthening of educational and clinical inferences applicable to practice.

The discrepancies observed between cadaveric and radiological measurements are best understood as reflections of inherent methodological differences rather than measurement errors. Cadaveric assessments, conducted through direct physical manipulation, are susceptible to postmortem tissue changes, loss of soft tissue elasticity, and potential distortion during dissection. Conversely, radiological measurements especially those obtained via PACS benefit from high-resolution imaging, digital precision, and standardized positioning that better reflects in vivo anatomy. These technical advantages enable more consistent identification of bony landmarks in radiographs. As such, the differences between the two modalities underscore their complementary strengths. Integrating both approaches can enhance the accuracy, depth, and contextual relevance of morphometric analyses, ultimately contributing to more robust anatomical and clinical insights.

On the other hand, cadaver-based education has become an essential component of modern surgical training, offering high-fidelity simulations that closely mimic real-life anatomical structures. This approach allows trainees to practice complex procedures such as hip arthroplasty in a safe and controlled environment, improving both technical skills and surgical confidence. Systematic reviews and participant feedback consistently emphasize its short-term effectiveness in skill acquisition and its perceived realism compared to live surgery [18-20]. For instance, hands-on cadaveric models have demonstrated clear benefits in procedures like transobturator tape surgery and trauma interventions, confirming their value in surgical skill development [21]. Despite limitations such as ethical concerns, high costs, and limited specimen availability, the consensus remains that cadaveric simulation bridges the gap between theoretical instruction and clinical practice, enhancing surgical competence and patient safety [18]. In this context, the anatomical measurements and visuals presented in our study offer practical value. By providing accurate reference points and morphometric data, these materials can further support cadaver-based training, contributing to the refinement of surgical techniques and the standardization of training protocols.

Limitations

One of the primary limitations of this study is the absence of radiological evaluation of cadaveric specimens. Ideally, the findings should have been correlated with radiological assessments conducted directly on cadavers to enhance the anatomical accuracy and clinical relevance of the results. However, due to institutional and administrative constraints, it was not feasible to transport cadavers to a hospital-based radiology center, where imaging is typically performed for clinical purposes only. As a result, radiological imaging of cadaveric specimens could not be incorporated into the methodology, which may have limited the comprehensive interpretation of morphometric findings. Additionally, the study was conducted on a limited number of cadaveric samples, which may restrict the generalizability of the results. Future studies involving a larger cadaver sample size are recommended to improve the statistical power and allow for broader anatomical variability to be assessed more accurately. Another limitation is the small number of female cadavers, which precluded sex-based comparisons. The unequal sex distribution in the cadaver sample (11 males, 3 females) posed a limitation in performing statistically valid comparisons between male and female specimens. Due to the small number of female cadavers, sex-specific analyses were not conducted. Instead, radiographic and cadaveric measurements were analyzed collectively, regardless of sex, and general mean values were calculated. This approach was adopted to ensure statistical feasibility and internal consistency. However, the lack of sex-stratified analysis may reduce the applicability of the findings to sex-specific anatomical variations. Therefore, this limitation should be acknowledged, and future studies should aim for a more balanced sex distribution to enable comparative analyses between male and female anatomy.

CONCLUSION

The findings of this study make a significant and original contribution by establishing standardized morphometric measurement protocols for key reference points in hip anatomy, based on data obtained through both cadaveric and radiological methods. To our knowledge, this is the first study to quantitatively compare morphometric measurements obtained through both cadaveric and radiological methods within the context of hip anatomy.

Our results support the hypothesis that standardized morphometric measurements enhance consistency and reliability in surgical applications. The first hypothesis of our study, stating that there are significant differences between Kirschner wire measurements on cadavers and anthropometric measurements from pelvic radiographs, was supported by our findings. The second hypothesis, proposing that Kirschner wire measurements before and after dissection are similar, was also confirmed. These results highlight the impact of measurement method on morphometric values while demonstrating that dissection does not significantly alter the spatial relationships of anatomical reference points. Moreover, the cadaveric measurements and anatomical visuals generated in this study provide students and residents with invaluable hands-on learning opportunities that reinforce theoretical knowledge through practical experience, thereby boosting surgical confidence and competence in a controlled and safe environment. However, limitations such as the inability to perform radiological imaging directly on cadaveric specimens and the relatively small sample size, especially the limited number of female cadavers, may restrict the generalizability of our findings and necessitate cautious interpretation.

In conclusion, this study underscores the importance of integrating both cadaveric and radiological data for precise and safe surgical outcomes. The established morphometric standards have the potential to improve the accuracy of minimally invasive hip procedures and enhance the overall quality of hip arthroplasty surgeries. These findings lay important groundwork for future research aimed at refining anatomical reference points and advancing orthopedic surgical practices, ultimately contributing to improved patient safety and surgical success.

Ethical Statement

Ethical approval for the use of cadavers was granted by the relevant institutional authorities, and the entire study was approved by the Non-Invasive Clinical Research Ethics Committee of Cukurova University Faculty of Medicine on November 8, 2024 (Decision No: 149/7)

Authors' Contribution

Study Conception: AGK, ÖSB; Study Design: AGK, ÖSB, MGB; Supervision: AGK, MGB; Funding: N/A; Materials: ÖSB, MGB, AGK; Data Collection and/or Processing: AGK, ÖSB; Statistical Analysis and/or Data Interpretation: AGK, ÖSB; Literature Review: AGK; Manuscript Preparation: AGK; and Critical Review: ÖSB, MGB.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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Generative Artificial Intelligence Statement

The author(s) declare that no artificial intelligence-based tools or applications were used during the preparation process of this manuscript. The all content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

Editor's note

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