

Innovations

Evaluation of Proximal Femur Geometry Using Digital Radiography and Dry Bone Measurements with its Clinical Implications

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Abstract

The femur is the longest and strongest bone in the human body that includes the head, neck, greater trochanter, and lesser trochanter, forming the ball-and-socket synovial hip joint. The angle formed by the neck's longitudinal axis with the shaft's longitudinal axis is known as the neck shaft angle, typically ranging from 115° to 140° in adults. Deviations from this range, such as coxavalga (angle >135°) or coxavara (angle <120°) can impact hip function. Orthopaedic procedures on the proximal femur aim to achieve a painless and functional hip in the long term. However, incorrectly reconstructed hip anatomy can lead to various complications, necessitating revision total hip replacement. To address this, focus on studying proximal femoral morphology to select implants that match the native hip anatomy closely is necessary. Conducting studies on proximal femur geometry in the Indian population, using radiographic and dry bone analyses, shall provide valuable insights to improve surgical outcomes. This knowledge can inform the development of implants tailored to the anatomical characteristics of the Indian population, enhancing patient satisfaction and reducing the risk of complications. The objective of the current study was to assess the morphology of the proximal femur, including its diameters and angles, and to compare the external and internal geometry of the femur as determined from radiographs with actual measurements on dry specimens within the Indian population. We found that the Femoral Head Length (FHL) was 49.62 ± 3.515 for dry bone and 40.56 ± 3.25 for radiographs, consistent with previous studies conducted in North India and elsewhere.

Similarly, the femoral neck proximal, middle, and distal anterior lengths were determined, showing differences between dry bone and radiographic measurements. The mean Neck-Shaft Angle (NSA) values for dry bone and digital radiography were 130.42 ± 85 and 128.6 ± 71 , respectively, indicating statistical significance. Other proximal dimensions, such as femoral head offset and vertical offset, also exhibited differences between dry bone and radiographic measurements. Notably, the Intertrochanteric Line Length (ITLL) was compared between dry bone and digital radiographs, showing significant differences. Interestingly, in our study, the Femoral Neck Anterior Length - Proximal (FNAL-P) values for dry bone (44.29 ± 7.34) were higher than FNAL-M (24.48 ± 3.74), suggesting variation in proximal femur morphology within the Indian population. These findings highlight the importance of assessing proximal femur morphology using both dry bone and radiographic analyses to understand differences and inform surgical interventions accurately.

Key words: Proximal femur morphology, Digital radiographs, Neck Shaft Angle, total hip replacement.

Introduction

The femur, the longest and strongest bone in the human body, consists of three main parts: the proximal end, shaft, and distal end. At the proximal end, it comprises the head, neck, greater trochanter, and lesser trochanter. Different populations have variants of genetic traits, and this causes numerous anatomical features to emerge. Anatomical features of the proximal femur vary according to age, sex, and race [1].

The anthropometry of the proximal femur embraces pronounced clinical significance in scheming implants and prostheses for femoral fractures of proximal region and hip joint arthroplasties. Surgical fixation with perfectly matched prosthesis shows a crucial role in improving long-standing treatment outcomes and preventing post-operative difficulties such as osteolysis with aseptic loosening and increased load [2].

The head of the femur articulates with the acetabulum of the hip bone, forming the ball and socket synovial hip joint. The hip joint is subjected to daily stresses as it tolerates the bulk of the upper body. Osteoarthritis of the hip may cause irreversible damage. Proximal geometry of the femur, such as neck-shaft angle and other measurements of femur are important in designing prostheses for a specific population. Most of the prostheses are designed and manufactured keeping the Western parameters and there is scarcity of data in other regions [3].

Prevalence of hip osteoarthritis, femoral neck fracture and other hip joint diseases are growing these days and Total hip arthroplasty is a commonly performed surgery. So there is always need of specific data for best fit prosthesis [4].

The femoral neck diameter is significant in orthopaedic surgery as screws used for fracture osteosynthesis transverse through the femoral neck to the head. Corrective osteotomies remain vibrant surgical procedures in the armamentarium of the orthopaedic surgeons, as these procedures are used to correct deformities, reshape the bone [5].

Innovation in the field of surgical orthopaedics especially joint replacement surgeries has shown a rapid development over the recent decades [6].

The angle created by the longitudinal axis of the neck with the longitudinal axis of the shaft of femur bone is termed as neck shaft or collo-diaphyseal angle. The neck shaft angle ranges from 115° to 140° , and an average of 126° in adults. When the angle $>135^{\circ}$, condition is known as coxavalga. When angle is $<120^{\circ}$, it is called as coxavara. The collodiaphyseal angle decreases with aging. This neck shaft angle allows the limb to swing clear of the pelvis during movements at the hip joint. It is highest in infants, decreases gradually with age, and the angle is greater in males than females [7].

The collodiaphyseal angle facilitates the clearance of the limb from the pelvis during movements at the hip joint [8].

Several methods are used to assess FNA, which may yield different values in the patients. While MRI and CT are used clinically, limitations with cost, scanning time and exposure to ionising radiation bound their applicability in longitudinal and population studies. More broadly, applicable measures such as ultrasound and functional tests exist, but they are limited by poor reliability and validity. These issues highlight the need for a valid and reliable universally acceptable method [9].

Dimensions of femur vary in different regional and ethnic groups, so population specific formula for estimation of femoral length is required [10].

However, despite the importance of this research, there is limited data available on the hip anatomy. Therefore, conducting studies on the proximal femur's geometry in the Indian population, using both radiographic and dry bone analyses, can provide valuable insights and help reduce the risk of complications associated with surgery. This knowledge can inform the development of implants tailored specifically to the anatomical characteristics thereby improving surgical outcomes and patient satisfaction.

Thereby the present study aims to evaluate the morphology of the proximal femur in relation to its various diameters and angles and compare the external and internal geometry of femur as obtained from radiographs with actual measurements on dry specimens.

Materials and Methods: The present study was evaluated and approved by the Ethics Committee of the SDUAHER, India with EC No. SDUMC/KLR/IEC/299/2023-24. This research received no external funding.

The femur bones were collected from the Department of Anatomy and Antero-posterior pelvic x-ray radiographs were collected from the Department of Radiology. The samples were selected based on the inclusion and exclusion criteria. This study was a Cross-Sectional analytic study done on 308 samples (dry bone 154 and x-ray radiograph 154). Intact Femora without any damage and digital radiographs with age group ranging between 20 to 60yrs were included in the study. Damaged femur bones and damaged x-rays were excluded from the study. The diseases which could modulate the outcome of the study, digital radiographs of patients with skeletally immature, osteoarthritis, injury of the study part of femur, metabolic bone diseases, malignancy, tumour, infectious lesions were also excluded.

Data was collected using pre validated instruments. The measurement tools such as Vernier caliper, goniometer, measuring scale were used for dry bone measurements and Moksha Digital Software MD vision version 1.3.6.696 was used for radiological measurements.

Specific outcome measures /variables

Parameters for dry bone : The parameters such as Femoral head diameter (FHL), Femoral neck anterior length -Proximal (FNAL- P), Femoral neck anterior length -Middle (FNAL- M), Femoral neck anterior length -Distal (FNAL- D), Femoral neck diameter (FND), Neck shaft angle (NSA), Femoral head offset (FHO), Vertical offset (VO), Femoral head neck axis length (HNAL) , Intertrochanteric line length (ITLL), Femoral proximal shaft diameter (FPSD) were measured in dry bones.

Parameters for digital radiograph : The parameters such as Femoral head diameter (RFHL), Femoral neck anterior length -Proximal (RFNAL- P), Femoral neck anterior length -Middle (RFNAL- M), Femoral neck anterior length -Distal (RFNAL- D), Femoral neck diameter (RFND), Neck shaft angle (RNSA), Femoral head offset (RFHO), Vertical offset (RVO), Femoral head neck axis length (RHNAL) , Intertrochanteric line length (RITLL), Femoral proximal shaft diameter (RFPSD) were measured in digital radiographs.

HL - The distance in a straight line between the upper end to the lower end of the femoral head in cranio caudal axis, FNAL – Anteriorly, it is measured was the distance between the inferior region of base of femoral head and the lower end of intertrochanteric line, FND – breadth of neck of femur in vertical axis , FNA – is the anterior inclination of the femoral neck in relation to the Trans condylar knee axis projected on a plane perpendicular to the shaft axis, NSA/CDA – angle between the line joining the center of head of femur and the midpoint of Intertrochanteric line (Femur Neck Axis) and vertical line from the tip of greater trochanter (Femur Shaft Axis), FHO – the distance between the center of head of femur and vertical axis drawn on femur, VO - was the vertical distance between proximal extent of lesser trochanter to the center of femoral head, FHNAL – is the straight-line distance between the extremities of the greater trochanter and femoral head in the sagittal plane, ITLL - The most proximal point of the greater trochanter to the lowest point of the lesser trochanter, FPSD - The coronal diameter of the femoral shaft, measured 3cm below the lesser trochanter

Statistical Analysis

The statistical analysis was done with mean, standard deviation, 95% CI, and the Range for each quantitative variable. The mean value was represented as mean \pm Standard deviation. For all correlations, P -value less than 0.05 was taken as Significant. Evaluation of relation was done using unpaired student t-test and chi-square test, respectively between measurements of proximal femur geometry in dry bone and radiograph. Analysis of variance was done to correlate between NSA as dependent variable and femoral head diameter, femoral neck length, diameter as independent variables. Statistical analysis was performed using IBM SPSS statics version 22.

Results

In our study, the Femoral Head Length (FHL) for dry bone and radiographs was 49.62 ± 3.515 and 40.56 ± 3.25 , respectively. These findings align with previous studies conducted in North India and elsewhere. The Femoral Neck proximal, middle, and distal anterior lengths for dry bone were 44.29 ± 7.34 , 24.48 ± 3.74 , and 24.48 ± 3.74 , respectively, while for radiographs, they were 35.28 ± 4.91 , 36.82 ± 6.53 , and 27.49 ± 5 , respectively. The mean Neck-Shaft Angle (NSA) values for dry bone and digital radiography were 130.42 ± 85 and 128.6 ± 71 , respectively, indicating statistical significance.

Additionally, other proximal dimensions, such as femoral head offset and vertical offset, showed differences between dry bone and radiographic measurements. The Intertrochanteric Line Length (ITLL) was compared between dry bone (58.06 ± 6.27) and digital radiographs (70.86 ± 9.02), revealing significant differences. Overall, various

morphometric measurements of the proximal femur exhibited statistically significant differences between dry bone and digital radiographs. Notably, dry bone values were generally lower than digital radiograph measurements, except for FHL, FNAL-P, NSA, and Femoral Head Offset (FHO). This contrasts with a similar study conducted by Vipin Sharma et al., where the Neck-Shaft Angle for dry bone was reported to be lower than that for digital radiographs. Importantly, in our study, the Femoral Neck Anterior Length - Proximal (FNAL-P) values for dry bone (44.29 ± 7.34) were higher than FNAL-M (24.48 ± 3.74).

Table 1 shows parameters of Proximal Femurs geometry using Digital Radiography and dry bone (Figure 1)

Parameters	Radiograph n=154 Mean±SD (mm)	Dry bone n=154 Mean±SD (mm)	P value	95% Confidence Interval of the Difference	
				Lower	Upper
FHL	40.56±3.25	49.62±3.515	<0.05	8.300	9.817
FNAL-P	35.28±4.91	44.29±7.34	<0.05	7.607	10.406
FNAL-M	36.82±6.53	24.48±3.74	<0.05	11.151	13.537
FNAL-D	27.49±5	21.27±3.04	<0.05	5.297	7.158
FND	36.01±4.1	30.86±3.56	<0.05	11.150	13.538
ITLL	70.86±9.02	58.06±6.27	<0.05	5.296	7.159
HNAL	100.25±6.87	87.47±7.98	<0.05	4.290	6.008
FPSD	32.12±2.15	28.06±3.22	<0.05	11.047	14.550
NSA	128.6±71	130.42±85	<0.05	11.111	14.448
FHO	38.23±6.02	42.53±5.89	<0.05	3.443	4.674
VO	62.23±7.61	49.9±6.74	<0.05	-5.627	-2.958

Table 2 shows parameters of Proximal Femur geometry of right and left femurs using Digital Radiography

Parameters	Radiograph (N = 154)		P value	95% Confidence Interval of the Difference	
	Left Mean±SD (mms) n= 77	Right Mean±SD (mm)n= 77		Lower	Upper
RFHL	49.58±3.369	49.65±3.677	.909	-1.188	1.058
RFNAL-P	44.26±7.188	44.31±7.526	.965	-2.395	2.291
RFNAL-M	36.79±6.522	36.86±6.577	.951	-2.150	2.020
RFNAL-D	27.48±5.030	27.51±5.046	.975	-1.630	1.578
RFND	35.99±4.175	36.04±4.018	.937	-1.357	1.253
RITLL	70.71±9.239	71.00±8.999	.846	-3.190	2.618
RHNAL	100.05±6.947	100.44±6.824	.726	-2.582	1.803
RFPSD	32.00±2.158	32.23±2.158	.502	-.921	.453
RNSA	130.09±1.756	130.12±1.709	.926	-.578	.526
RFHO	38.23±6.035	38.23±6.037	1.00	-1.922	1.922
RVO	62.00±7.688	62.53±7.575	.666	-2.963	1.898

Table 3 shows parameters of Proximal Femur geometry of right and left femurs using dry bone

Parameters	Dry bone (N = 154)		P value	95% Confidence Interval of the Difference	
	Left Mean±SD (mm)n= 71	Right Mean±SD (mm)n= 83		Lower	Upper
FHL	40.56±3.060	40.55±3.419	.986	-1.032	1.050
FNAL-P	23.94±3.695	24.94±3.740	.108	-2.835	.283
FNAL-M	23.94±3.695	24.94±3.740	.100	-2.184	.192
FNAL-D	21.54±3.028	21.04±3.042	.311	-.470	1.469
FND	30.77±3.473	30.94±3.650	.775	-1.305	.975
ITLL	58.07±6.186	58.05±6.386	.983	-1.988	2.033
HNAL	86.01±9.586	88.71±6.070	.036	-5.216	-.178
FPSD	28.38±3.109	27.78±3.313	.253	-.432	1.626
NSA	129.27±4.968	129.42±4.395	.838	-1.645	1.337
FHO	43.24±6.341	41.92±5.433	.165	-.551	3.198
VO	49.96±7.511	50.01±6.056	.960	-2.215	2.106



Figure 1 showing parameters measured in dry femur

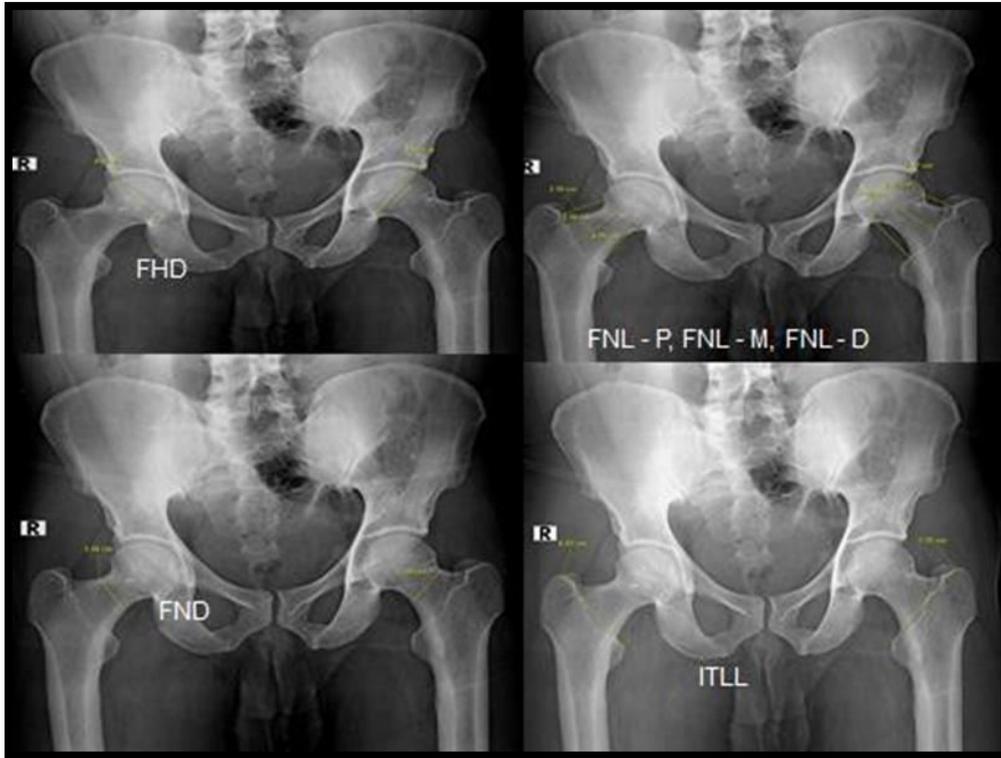


Figure 2 showing measurements of femur on radiographs

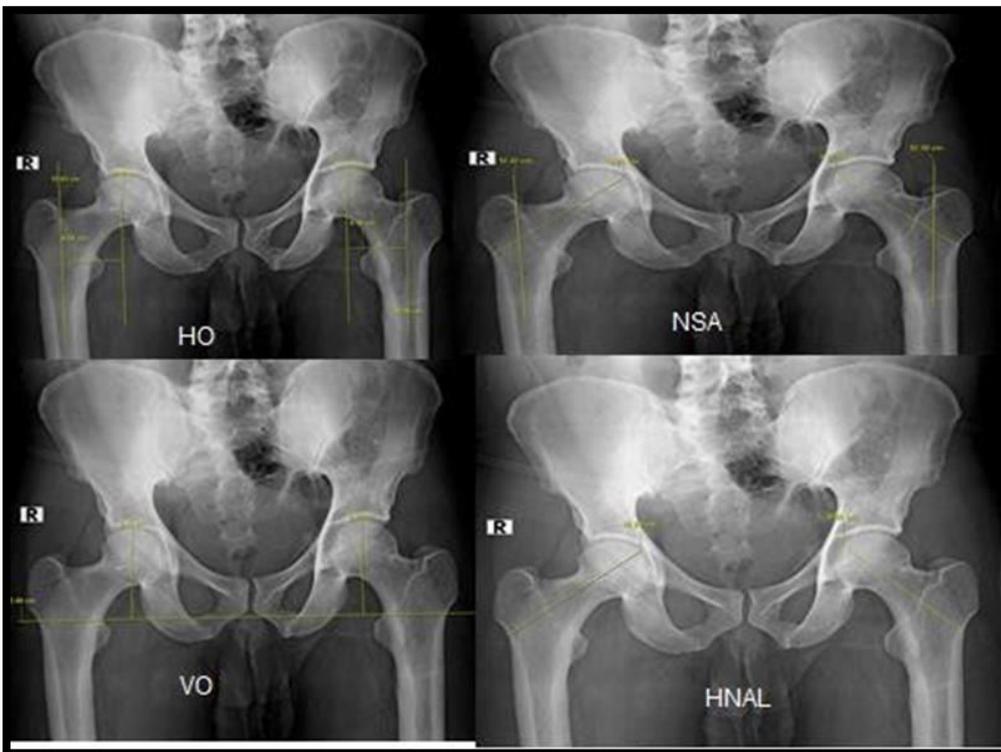


Figure 3 showing other measurements of femur on radiographs

Discussion

The femur, being one of the frequently used long bones for stature estimation, plays a significant role in forensic investigations and identity determination. Anthropometric dimensions exhibit variation among different population groups, influenced by genetic and environmental factors affecting growth and development. Beyond treatment considerations, stature serves as a crucial anthropometric parameter for establishing an individual's identity in medico-legal contexts, particularly in skeletal remains examination.

Table 4 (A,B,C) showing comparison of present study parameters of proximal femur using digital radiography and dry bone with previous studies.

A.

	Present study n= 154 Digital radiography Patients	Present study n= 154 Dry bone measurements	Mayank Gupta et al. N= 96 Dry bone 2022 [2]	SajanS karia et al. N =300 Dry bone Measurements 2022 [3]	O.I. Akinmoku et al. N=56 Dry bone Measurements 2021 [5]	Anil Kumar Dwivedi et al. N= 280 Dry bone Measurements 2019 [10]
Population	Indian	Indian	Indian	Indian	Nigerian	Indian
FHL	40.56±3.25	49.62±3.5	41.59±3.3	-	-	40.6± 3.5
FNAL-P	35.28±4.91	44.29±7.34	36.06±4.9	-	0.872	29.96±4.23
FNAL-M	36.82±6.53	24.48±3.74	-	-	-	96.9 ± 6.9
FNAL-D	27.49±5	21.27±3.04	-	-	-	-
FND	36.01±4.1	30.86±3.56	29.45±3.3	-	0.5445	27.78±2.8

ITLL	70.86±9 .02	58.06±6. 27	41.92±3. 9	-	0.7701	45.8 ±2.0
HNAL	100.25± 6.9	87.47±7. 98	-	-	0.8198	96.9 ± 6.9
FPSD	32.12±2 .2	28.06±3. 22	-	-	0.8994	82.23 ± 6.2
NSA	128.6±7 1	130.42±8 5	119.1±5. 2	<0.000 1	0.6539	130.8 ± 7.3
FHO	38.23±6 .02	42.53±5. 89	-	-	-	-
VO	62.23±7 .61	49.9±6.7 4	-	-	-	-

B.

	Present study n= 154 Digital radiography Patients	Present study n= 154 Dry bone measurements	Rajeev Mukhia et al. N= 75 Dry bone Measurements 2018 [11]	Vipin Sharma et al. N = 66 Digital radiography Patients 2018 [12]	Vipin Sharma et al. N = 77 Dry bone Measurements 2018 [12]	Rajeev Mukhia et al. N= 75 Dry bone Measurements 2018 [13]	Zaki. n=380 Digital radiography Patients 2017 [15]
population	Indian	Indian	Nepalese	Indian	Indian	Nepalese	Turkish
FHL	.909	49.6± 3.5	0.17	--	-	0.17	0.001
FNAL-P	.965	44.29±7.3	0.26	-	-	0.26	-
FNAL-M	.951	24.48±3.7	-	-	-	-	0.09
FNAL-D	.975	21.27±3.0 4	-	-	-	-	-

FND	.937	30.86±3.56	0.17	-	-	0.17	0.11
ITLL	.846	58.06±6.27	-	-	-	-	-
HNAL	.726	87.47±7.98	-	-	-	-	0.05
FPSD	.502	28.06±3.22	-	-	-	-	-
NSA	.926	130.42±85	0.03	127.2±2.50	126.2±2.50	0.03	0.38
FHO	1.00	42.53±5.89	-	-	-	-	0.04
VO	.666	49.9±6.74	-	-	-	-	--

C.

	Present study n= 154 Digital radiography Patients	Present study n= 154 Dry bone measurements	TercioHenric et al. N = 500 Digital radiography 2015 [23]	TercioHenric et al. N = 500 Digital radiography 2015 [23]	Sanchita Roy et al., (n=102) Digital radiography 2014 [24]	SubhashGujar et al. N =250 Dry bone Measurements 2013 [25]	Kaur P. et al. N = 280 Digital radiography 2013 [26]	Robinson Estes Santos Pires et al. N =305 Digital radiography 2011 [27]	HavvaTala yCalis et al. N = 232 Digital radiography 2004 [28]
population	Indian	India n	Brazil	Brazil	Indian	Indian	Indian	Brazil	Turkish
FHL	40.56±3.25	49.6±3.5	-	-	4.67±0.5	-	-	-	.234

FNAL-P	35.28± 4.91	44.29 ±7.3	-	36.65 ±5.37	-	>0.05	-	35.7± 6.4	-
FNAL-M	36.82± 6.53	24.48 ±3.7	>0.00 1	-	-	-	-	-	-
FNAL-D	27.49± 5	21.27 ±3.04	-	-	-	-	-	-	-
FND	36.01± 4.1	30.86 ±3.56	<0.00 1	37.7± 4.8	-	-	-	36.6± 4.8	.787
ITLL	70.86± 9.02	58.06 ±6.27	-	-	-	-	-	-	.291
HNAL	100.25 ±6.9	87.47 ±7.98	0.519	108.3 ±9	-	-	-	113.4 ± 9.7	.741
FPSD	32.12± 2.2	28.06 ±3.22	-	-	-	-	0.009	-	.706
NSA	128.6± 71	130.4 2±85	0.103	130.96 ±9.4	130.99 +3.8	>0.05	--	129.2 ±5.5	.975
FHO	38.23± 6.02	42.53 ±5.89	0.519	44.03 ±8.13	3.86+ 0.47	-	-	-	-
VO	62.23± 7.61	49.9± 6.74	-	-	-	-	-	-	-

Overall comparisons revealed that dry bone values were lower than digital radiograph measurements, except for Femoral Head Length (FHL), Femoral Neck Anterior Length - Proximal (FNAL-P), Neck-Shaft Angle (NSA), and Femoral Head Offset (FHO). As per our study the FNAL-P (44.29±7.34) values for dry bone were more than FNAL-M (24.48±3.74) which contradict the similar study done by Anil Kumar Dwivedi et al. where FNAL-P (29.96± 4.23) values are less than FNAL-M (96.9 ± 6.9) [10]. This contrasts with a similar study conducted by Vipin Sharma et al., where the Neck-Shaft Angle for dry bone was reported to be lower than that for digital radiographs [12].

In our study, various morphometric measurements of the proximal femur exhibited statistically significant differences between dry bone and digital radiographs.

The femoral neck proximal, middle, and distal anterior lengths obtained from our study for dry bone were 44.29±7.34, 24.48±3.74, and 24.48±3.74, respectively. For radiographs, these measurements were 35.28±4.91, 36.82±6.53, and 27.49±5, respectively. We compared these results with similar studies conducted by Mayank Gupta et al., Minakshi Verma et al., and Anil Kumar Dwivedi et al. for dry bone, and

Sanchita Roy et al. and Robinson Esteves Santos Pires et al. for digital radiographs. In these studies, single femoral neck anterior length measurements were taken, which are comparable to our findings.

Our study revealed statistically significant differences in femoral neck and proximal shaft diameter when comparing dry bone (30.86 ± 3.56 , 28.06 ± 3.22) to digital radiographs (36.01 ± 4.1 , 32.12 ± 2.15). Similar findings were reported by Tercio Henric et al. in the Brazilian population and Kaur P. et al. in the Indian population (digital radiographs), indicating statistically significant differences in femoral neck and proximal shaft diameter across different populations[23].

The Femoral Neck Axial Length (HNAL) measurements obtained in our study were noted to be shorter for both dry bone (87.47 ± 7.98) and digital radiographs (100.25 ± 6.9) compared to values documented in studies on the Nigerian and Brazilian populations. Specifically, in the study by O.I. Akinmokun et al. on dry bone, the HNAL was reported as 96.9 ± 6.9 , while in the study by Tercio Henric et al. on digital radiographs, it was reported as 108.27 ± 9 .

These findings suggest variations in Femoral Neck Axial Length across different populations, emphasizing the importance of considering population-specific factors in clinical assessments and surgical interventions involving the femoral neck [23].

Understanding the average value and range of Femoral Neck Axial Length (FNAL) in a population is crucial for implant manufacturers to determine the appropriate length of hip screws required to serve the population effectively.

No significant differences were observed between the right and left sides in digital radiographs, similar to findings in dry bone specimens, except for the femoral head-neck axis length (HNAL) where a significance with a p-value of 0.036 was noted. This contrasts with the results of studies conducted by Turk Toplumunda et al. for digital radiographs where significance was found, as well as TercioHenric et al. for digital radiographs, and O.I. Akinmokun et al. for dry bone specimen [23].

However, when comparing the same parameters individually between the right and left sides of both dry bone and radiographs, no statistical significance was found.

However, it's noteworthy that similar studies conducted by Minakshi Verma et al. for dry bone, Tercio Henric et al., and Sanchita Roy et al. for radiographs did not reveal statistically significant differences in these measurements. This indicates potential variability in proximal femoral dimensions across different populations and

underscores the importance of considering population-specific factors in preoperative planning and surgical interventions[24].

Intertrochanteric fractures of the femur are common, particularly among the elderly, often requiring surgical nail fixation for treatment. In our study, we compared the mean value of the Intertrochanteric Line Length (ITLL) for dry bone (58.06 ± 6.27) and digital radiographs (70.86 ± 9.02) with similar studies conducted on different populations.

Preoperative assessment of the neck-shaft angle (NSA) is crucial for various surgical procedures, especially total hip arthroplasty, as it aids in understanding normal acetabular and proximal femoral morphology. The NSA is specific to individuals and varies across populations, genders, and races, making it essential for preoperative planning.

In recent years, there has been a significant increase in the frequency of total hip arthroplasties and hip revision surgeries worldwide. Studies indicate a projected surge in demand for primary total hip arthroplasties over the next decade, encompassing all countries, including India. Notably, India has witnessed an annual performance of 1000-2500 total hip arthroplasties over the past decade, with a growing preference for uncemented total hip arthroplasty from 2006 to 2019[26]. With this rising trend in hip surgeries, anthropometric measurements of the proximal femur emerge as invaluable tools for optimizing the design of femoral implants and prostheses, ensuring better fit and improved treatment outcomes.

A critical aspect of successful total hip arthroplasty lies in the design of the femoral head prosthesis. While oversized heads are increasingly favored due to reduced dislocation risks, they can introduce various complications, including wear, biomechanical issues, and groin pain. Therefore, precise evaluation of femoral head diameters, considering regional variations, is essential for effective total hip replacement procedures.

In our study, the mean NSA values for dry bone and digital radiography of the femur were determined to be 130.42 ± 85 and 128.6 ± 71 , respectively, showing statistical significance. This emphasizes the importance of understanding NSA variations in different populations, genders, and races to ensure accurate preoperative planning and successful surgical outcomes, particularly in procedures like total hip arthroplasty [27].

The other proximal dimensions obtained from our study included femoral head offset and vertical offset, with values of 42.53 ± 5.89 and 49.9 ± 6.74 for dry bone, and 38.23 ± 6.02 and 62.23 ± 7.61 for radiographs, respectively. These measurements

demonstrated statistically significant differences compared to similar studies conducted by Turk Toplumunda et al. for radiological studies.

Previous studies have primarily focused on femur anthropometric measurements using either dry bone or radiographic methods separately. However, comprehensive studies combining both dry bone and radiographic analyses have been limited. Moreover, our study introduces novel parameters such as Femoral Neck Anterior Length - Middle, Femoral Neck Anterior Length - Proximal, and Femoral Neck Anterior Length - Distal.

While previous studies have examined femoral neck anterior length as a single measurement, our study is the first to measure it at three different sites, providing an added advantage for future reconstructive surgeries and prosthesis design.

In our study, the Femoral Head Length for dry bone and radiograph was found to be 49.62 ± 3.515 and 40.56 ± 3.25 , respectively. These findings align with studies conducted in North India by Mayank Gupta et al., Minakshi Verma et al., and Anil Kumar Dwivedi et al. for dry bone, and Sanchita Roy et al., Turk Toplumunda et al., and Havva Talay Calis et al. for digital radiographs. In those studies, the average head diameter was reported as 41.59 ± 3.25 mm, 42.32 ± 4.11 mm, 40.57 ± 3.5 mm for dry bone and 4.67 ± 0.52 , 0.001, and 0.234 for digital radiographs, respectively. [28].

We found significant differences in comparison to studies such as Mayank Gupta et al. and O.I. Akinmokun et al. in the Nigerian population, where ITLL for dry bone was reported as 41.92 ± 3.90 and 45.8 ± 2 , respectively. Additionally, in the study by Havva Talay Calis et al. on the Turkish population, the Radiographic Intertrochanteric Line Length (RITLL) was reported as 0.291.

These differences underscore the variability in Intertrochanteric Line Length across different populations, highlighting the importance of considering population-specific factors in the treatment and management of intertrochanteric femur fractures [28].

Conclusions

This study underscores the importance of understanding proximal femur morphometry by comparing values observed in both dry bone and digital radiographs. While notable differences exist between these imaging methods, minimal variations were found between the right and left sides, except for the length of the femoral head and neck axis in dry bone. Knowledge of anthropometric measurements and bone morphology is invaluable for clinicians in identifying fracture risk factors. Given advancements in surgical techniques like Hemiarthroplasty and Total Hip Replacement, a comprehensive grasp of normal proximal femur anatomy and variations is essential. This understanding is particularly critical for selecting appropriate implants in surgical interventions for

peri-trochanteric fractures, which often yield high success rates with rehabilitative measures involving implants or prostheses. The examination of morphometric and radiological features of the proximal femur aids in precise implant selection, ultimately enhancing surgical outcomes.

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