Morphometric Study of the Proximal Femur in Normal Egyptian Individuals (Aged One To Sixty Years)

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Abstract: Background: Hip fractures are a major problem for elderly people nowadays. The shape of proximal femur is known to be an important risk factor for hip fractures. Also the treatment of those fractures uses implants which are based in proximal femur measurements. **Aim of the work:** the present work aimed to study the measurements of the proximal femur in living Egyptian individuals in relation to age, sex, side, height and length of the femoral shaft by using radiography and in adult dried femurs in relation to sex, side, length of the femoral shaft. **Materials and methods:** This study was carried out on 250 living Egyptian human individuals divided into five age groups 1st group from 1 year up to < 6 years, 2nd group from 6 years up to <12 years, 3rd group from 12 years up to < 20 years, 4th group from 20 years up to < 40 years, 5th group from 40 years to 60 years subjected to pelvic radiographs. *The following parameters were obtained,* Hip axis length (HAL), femoral neck axis length (FNAL), femoral head width (FHW), femoral neck width (FNW), intertrochanteric width (ITW), cervicodiaphyseal angle (Q angle), femoral offset and length of femoral neck (LFN). As regards the 100 dried human femurs, *A sagittal section of their proximal parts was done then photographed. The following parameters were obtained,* femoral neck axis length (FNAL), femoral head width (FHW), femoral neck width (FNW), intertrochanteric width (ITW), cervicodiaphyseal angle (Q angle), femoral offset and length of femoral neck (LFN). **Results:** Regarding the radiological cases, we found that the maximum increase of the linear femoral measurements occurs between the third (12-20 years) and the fourth age group (20-40 years). But the cervicodiaphyseal angle showed maximum decrease between the first (<6 years) and second (12-20 years) age groups. Also this study showed strong positive correlations between age and HAL, FNAL, FHW, FNW, ITW and Q angle. The measurements obtained in this study presented some variations which were statistically significant in comparison with previous studies. This study showed significant differences of sex and side measures. **Conclusion:** From this study we conclude that the maximum increase of the proximal femoral measurements occurs between age of 12-40 years. While the cervicodiaphyseal angle (Q angle) showed maximum decrease between age of 1-20 years.

1. Introduction

There are metric differences in skeletal components among populations and these variations are related to genetic and environmental factors as geography, diet and life style. The variations in human skeletal measurements determine the racial characteristics of the populations; show up regional diversity between different populations or within the same population and also offer a guide to clinicians for the determination of risk factors for fractures. Alonso CG et al.., 2002. **(1).**

Hip fractures are a major problem for the elderly people nowadays. The shape of proximal femur is known to be an important risk factor for hip fractures of the femoral neck, suggesting that the morphometry of the proximal femur may contribute to femoral neck strength. **Gregory JS et al., 2004 (2).**

Many studies have been carried out to define risk factors for hip fractures in order to identify those at risk and hence to prevent fractures and also to evaluate adequability of implants used in treatment of these fractures as fixed angle plates and hip prostheses. Several studies found relation between the proximal femur morphometry and its mechanical strength and resistance to impact any stress. Highest values were found in races with a higher incidence of hip fractures. Hoagland and Low, 1980 **(3).**

The present study aimed to study the measurements of the proximal femur in living Egyptian individuals in relation to age, sex, side, height and length of femoral shaft by using radiography. And the measurements of the proximal femur in adult dried femurs in relation to sex, side and length of femoral shaft.

2. Materials and Methods

This study was carried out on 270 living human Egyptian individuals of both sexes and 130 dried human femurs.

Regarding the 270 living human Egyptian individuals, Each individual was subjected for full history taking. 20 individuals were excluded from this study having metabolic bone diseases, terminal diseases, malignancy, renal failure and coxarthrosis. Then the 250 living human Egyptian individuals were divided into five age groups as follows:- First group from 1 year up to < 6 years (20 individuals), Second group from 6 years up to <12 years (20 individuals), Third group from 12 years up to < 20 years (20 individuals), Fourth group from 20 years up to < 40 years (100 individuals), Fifth group from 40 years to 60 years (90 individuals). Pelvic radiographs were obtained using standardized protocol:- In 15-30 degrees of internal rotation of the hips for the previously mentioned individuals in the supine position with a film focus distance of 100 cm and the beam centered on the symphysis pubis. Morphometric measurements were performed on each side. The following measurements were applied :- Hip axis length (HAL) (A-B):- Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the inner pelvic brim, Femoral neck axis length (FNAL) (C-D):- Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris (fovea), Length of femoral neck (FNL) (M-N):- The distance between the center of the head and the intertrochanteric line, Femoral head width (FHW) (E-F):- Broadest cross section of the femoral head, Femoral neck width (FNW) (G-H):- Narrowest cross section of the femoral neck in its middle third, Intertrochanteric width (TW) (I-J):- Cross section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter, Cervical – diaphyseal angle (CD angle) (C-K-L):- Angle between the axis of the femoral neck and femur shaft and Femoral offset (OS) (O-P):- Distance between the femoral head and femoral diaphyseal shaft. Then the morphometric parameters were analyzed statistically in relation to age, sex, side, height of the individual and length of the femoral shaft. We calculated the mean ± standard error for each anthropometric and morphometric parameters. The Pearson linear correlation was performed using the SPSS 10.0 software.
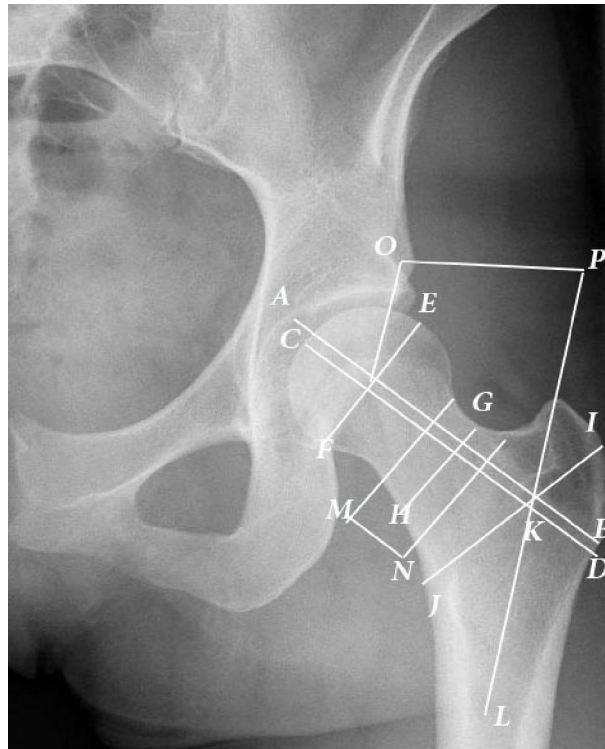

Figure (1) A photograph of plain x-ray of the hip joint showing the parameters measured from the anteroposterior roentgenograms of the proximal femur. Hip axis length (HAL) (A-B), Femoral neck axis length (FNAL) (C-D), Length of femoral neck (FNL) (M-N), Femoral head width (FHW) (E-F), Femoral neck width (FNW) (G-H), Intertrochanteric width (TW) (I-J), Cervical – diaphyseal angle (CD angle) (C-K-L) and Femoral offset (OS) (O-P).

Regarding the 130 dried human femurs, they were collected but 30 dried femurs were excluded from this study having bone defects, damage, visible previous procedures, and signals of undergont bone fixation, visible tumors or deformities. After their collection, A sagittal section of their proximal parts was done then they were photographed using portable diagnostic model FNX 200, with Kodak-branded film measuring 30x40cm. The images were obtained with a distance of the bulb chassis of 100 cm, using a power of 75kV and 10mA. We used the anterior-posterior incidence with the femur in internal rotation, placing the lesser trochanter in contact with the chassis. The following measurements were obtained in millimeters with vernier caliber**.** Femoral neck axis length (FNAL) (C-D), Length of femoral neck(FNL) (M-N), Femoral head width (FHW) (E-F)*,* Femoral neck width (FNW) (G-H)*,* Intertrochanteric width (TW) (I-J), Cervical – diaphyseal angle (CD angle) (C-K-L) and Femoral offset (OS) (O-P). The morphometric parameters were measured and statistically analysed.
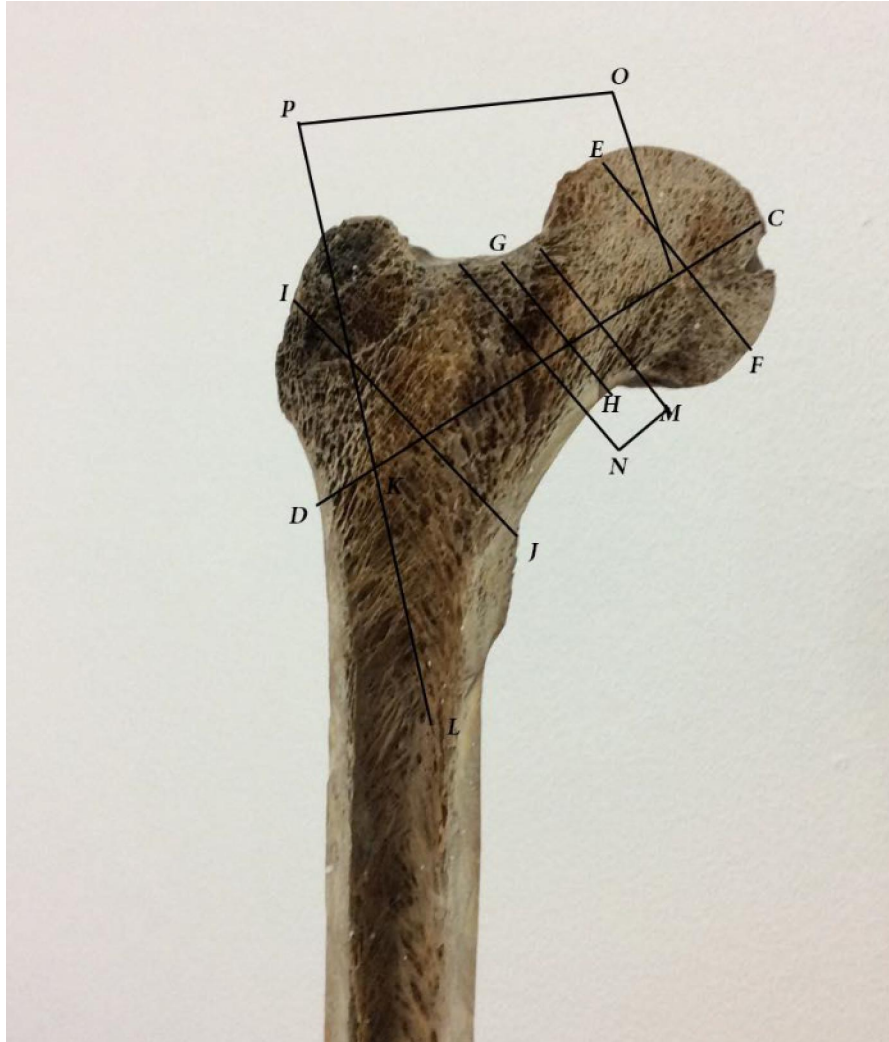

Figure (2) A mid sagittal section of the proximal end and upper part of the shaft of right dried femur showing the following parameters : C-D (Femoral neck axis length "FNAL"), E-F (Femoral head width "FHW"), G-H (Femoral neck width "FNW"), I-J (Intertrochanteric width "ITW"), CKL (cervico-diaphyseal angle "Q angle"), M-N (Length of femoral neck), O-P (Femoral offset).

3. Results

As regards the 250 radiological case, **Table (1)** shows that the mean (HAL) was 72.52 mm in second age group (6-<12 years), in third age group (12-<20 years) was 80.33 mm, in fourth age group (20-<40 years) was 106.58 mm, in fifth age group (40-60 years) was 116.2 mm, not identified in first age group (< 6 years). The mean (FNAL) was 66.78 mm in the second age group, in third age group was 75.1 mm, in fourth age group was 98.66 mm, in fifth age group

was 106.69 mm, not identified in first age group. The mean (FHW) was 35.57 mm in first age group, in second age group was 31.93 mm, in third age group was 38.12 mm, in fourth age group was 51.27 mm, in fifth age group was 53.5 mm. The mean (FNW) was 30.69 mm in first age group, in second age group was 21.24 mm, in third age group was 25.21 mm, in fourth age group was 35.34 mm, in fifth age group was 37.95 mm. The mean (ITW) was 73.42 mm in first age group, in second age group was 44.17 mm, in third age group was 54.05 mm, in fourth age group was 77.02 mm, in fifth age group was 82.91 mm. The mean (Q angle) was 150.82 degrees in first age group,

in second age group was 134.92 degrees, in third age group was 130.91 degrees, in fourth age group was 130.59 degrees, in fifth age group was 130.3 degrees. The mean femoral offset was 39.73 mm in second age group, in third age group was 41.48 mm, in fourth age group was 39.75 mm, in fifth age group was 40.6 mm, not identified in first age group. The mean (LFN) was 35.8 mm in second age group, in third age group was 37.31 mm, in fourth age group was 39.49 mm, in fifth age group was 37.15 mm, not identified in first age group. The difference of the results between the age groups was statistically significant (p value <0.001).

Table (1) shows the normal variables of the proximal femur: Hip axis length (HAL), Femoral neck axis length (FNAL), Femoral head width (FHW), Femoral neck width (FNW), Intertrochanteric width (ITW), Q angle, Femoral offset, Length of the femoral neck, length of the femoral shaft and height of the individual according to age groups.

Variable	1 -<6 y (20) Mean± SD (mm)	6 - <12 y (20) Mean±SD (mm)	12 - <20 y (20) Mean± SD (mm)	20 - <40 y (100) Mean± SD (mm)	40-60 y (90) Mean± SD (mm)	F test	P value
HAL	-	72.52±36.44	80.33±18.67	106.58±17.05	116.2±15.84	40.67	0.001**
FNAL	-	66.78±33.27	75.1±19.45	98.66±15.36	106.69±15.38	37.95	0.001**
FHW	35.57±8.59	31.93±14.91	38.12±10.64	51.27±7.97	53.5±8.12	43.01	0.001**
FNW	30.69±8.52	21.24±10.21	25.21±7.25	35.34±6.57	37.95±4.9	37.61	0.001**
ITW	73.42±16.73	44.17±17.95	54.05±16.98	77.02±13.78	82.91±11.21	44.13	0.001**
Q angle (degree)	150.82±9.74	134.92±1.33	130.91±4.87	130.59±6.83	130.3±8.15	36.72	0.001**
F offset	-	39.73±3.78	41.48±3.6	39.75±5.16	40.6±7.41	0.669	0.572
LFN	-	35.8±3.38	37.31±3.47	39.49±4.48	37.15±3.84	7.9	0.001**
Length	19.19±0.74	30.53±0.31	34.15±1.85	34.41±2.47	35.09±2.16	253.6	0.001**
Height	122.67±2.61	154.24±0.32	167.68±2.8	166.36±5.02	166.96±7.22	304.78	0.001**
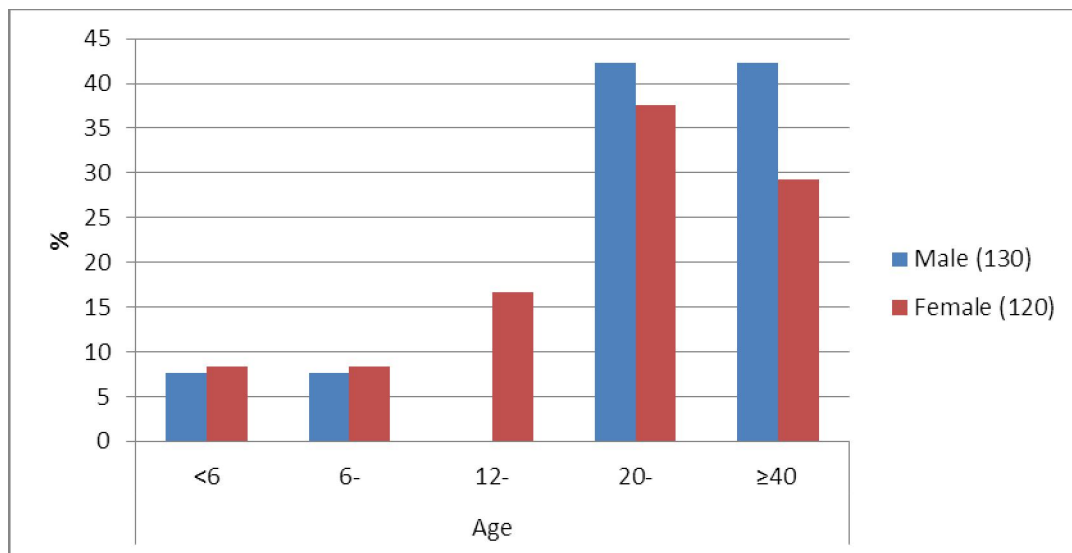
Histogram (1) shows the percentages of number of femurs in different age groups.

Table (2) shows the percent changes of the mean result of each proximal femur morphometric

measurement. The mean hip axis length (HAL) increased by 10.77 % between second and third age

groups, 32.68 % between third and fourth age groups, 9.03 % between fourth and fifth age groups. The mean femoral neck axis length (FNAL) increased by 12.46 % between second and third age groups, 31.37 % between third and fourth age groups, 2.06 % between fourth and fifth age groups. The mean femoral head width (FHW) decreased by 10.23 % between first and second age groups, increased by 19.39 % between second and third age groups, 34.5 % between third and fourth age groups, 4.35 % between fourth and fifth age groups. The mean femoral neck width (FNW) decreased by 30.79 % between first and second age groups, increased by 18.69 % between second and third age groups, 40.18 % between third and fourth age groups, 7.39 % between fourth and fifth age groups. The mean intertrochanteric width (ITW) decreased by 39.84 % between first and second age groups, increased by 22.37 % between second and third age groups, 42.5 % between third and fourth age

groups, 7.65 % between fourth and fifth age groups. The cervicodiaphyseal angle (Q angle) decreased by 10.54 % between first and second age groups, 2.97 % between second and third age groups, 0.24 % between third and fourth age groups, 0.22 % between fourth and fifth age groups. The mean femoral offset increased by 4.41 % between second and third age groups, decreased by 4.17 % between third and fourth age groups, then increased again by 2.14 % between fourth and fifth age groups. The mean length of the femoral neck increased by 4.22 % between second and third age groups, 5.84 % between third and fourth age groups, then decreased by 5.93 % between fourth and fifth age groups. This means that the maximum increase of the linear femoral measurements occurs between the third and the fourth age groups. But the cervicodiaphyseal angle showed maximum decrease between the first and second age groups.

Table (2). Percent changes of the mean results of the proximal femur measurements across different age groups.

	<6 y to 6-<12 y	6-<12 y to 12- <20 y	12-<20 y to 20- <40 y	20- <40 y to ≥40 y
HAL	-	10.77%	32.68%	9.03%
FNAL	-	12.46%	31.37%	2.06%
FHW	-10.23%	19.39%	34.5%	4.35%
FNW	-30.79%	18.69%	40.18%	7.39%
ITW	-39.84%	22.37%	42.5%	7.65%
Q angle	-10.54%	-2.97%	-0.24%	-0.22%
F offset	-	4.41%	-4.17%	2.14%
LFN	-	4.22%	5.84%	-5.93%
Length	59.09%	11.86%	0.76%	1.98%
Height	25.74%	8.71%	-0.79%	0.36%

In this study, the Pearson's linear correlation coefficients between age and proximal femoral morphometric parameters were calculated to evaluate the relationship between age and proximal femur morphometry. The strongly positive correlations were found between age & HAL (r = 0.0407, p = 0.001), age & FNAL (r = 0.398, p = 0.001), age & FHW (r = 0.496, p = 0.001), age & FNW (r = 0.435, p = 0.001), age & ITW (r = 0.407, p = 0.001), age & Q angle (r = 0.386, p = 0.001). **Table (3).**

Table (3). Correlation coefficients between age and proximal femur morphometric measurements.

	Age	
	R	P
HAL	0.407	0.001
FNAL	0.398	0.001
FHW	0.496	0.001
FNW	0.435	0.001
ITW	0.407	0.001
Q angle	-0.386	0.001
F offset	0.058	0.378
LFN	-0.093	0.158
Length	0.535	0.001
Height	0.513	0.001
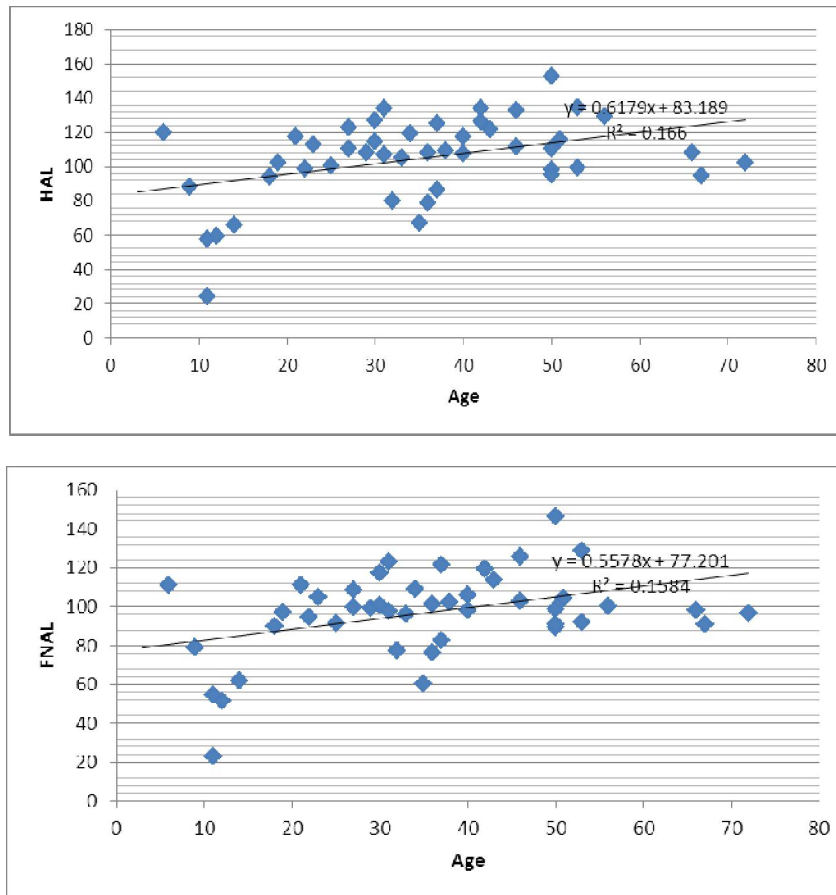
Histogram (2) shows strong positive correlation coefficients between age and HAL, age and FNAL.

As regards the 100 dried human femurs, **Table (4)** showed that The mean (FNAL) was 94.63 mm in male femurs, while in female femurs was 94.23 mm. The mean (FHW) was 62.41 mm in male femurs, while in female femurs was 53.37 mm. The mean (FNW) was 34.73 mm in male femurs, while in female femurs was 36.5 mm. The mean (ITW) was 84.32 mm in male femurs, while in female femurs was 58.64 mm. The mean (Q angle) was 134.72 degrees in male femurs, while in female femurs was 130.67 degrees. The mean femoral offset was 34.74 mm in male femurs, while in female femurs was 44.5 mm. The mean length of the femoral neck (LFN) was 40.42 mm in male femurs, while in female femurs was 37.82 mm. So sex has effect on (FHW), (FNW), (ITW), (Q angle), femoral offset and (LFN), but it has no effect on femoral neck axis length (FNAL).

Table (4) shows the normal variables of the proximal femur: Femoral neck axis length (FNAL), Femoral head width (FHW), Femoral neck width (FNW), Intertrochanteric width (ITW), Q angle, Femoral offset, Length of the femoral neck and length of the femoral shaft according to sex.

Variable	Male (60) Mean± SD, Range (mm)	Female (40) Mean± SD, Range (mm)	Student t test	P value
FNAL	94.63±4.46,89.3-100.14	94.23±3.04,91.22-97.23	0.505	0.615
FHW	62.41±19.34,48.58- 89.54	53.37±2.13,51.27-55.47	2.94	0.004**
FNW	34.73±1.3,33.25-36.39	36.5±0.68,35.82-37.17	7.89	0.001**
ITW	84.32±3.75,80.5-89.36	58.64±20.98,37.92-79.35	9.29	0.001**
Q angle (degree)	134.72±2.4,131.5-137.17	130.67±1.29,129.4-131.94	9.78	0.001**
F offset	34.74±4.51,29.3-40.25	44.5±1.97,42.55-46.45	12.88	0.001**

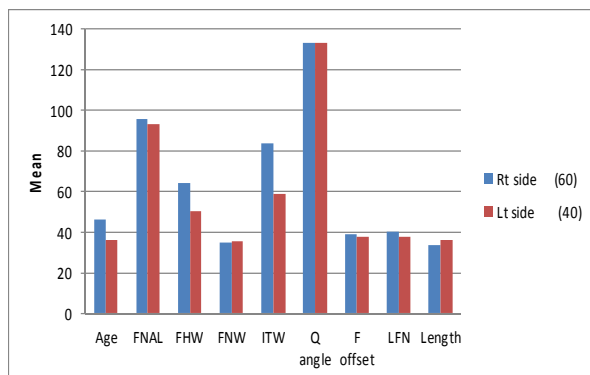| LFN | 40.42±3.18,37.2-44.71 | 37.82±0.63,37.2-38.44 | 5.1 | 0.001** |
| Length of femoral shaft | 34.52±0.72, 33.56-35.28 | 34.81±2.16, 32.67-36.94 | 0.936 | 0.352 |
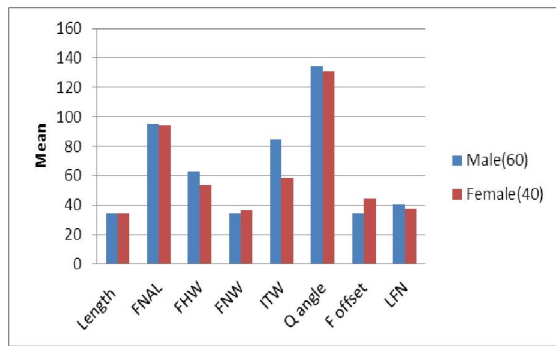
Histogram (3) shows the normal variables of the proximal femur according to sex.

As regards the side difference, **Table (5)** showed that The mean (FNAL) was 95.56 mm in

right femurs, while in left femurs was 92.84 mm. The mean (FHW) was 64.53 mm in right femurs, while in left femurs was 50.2 mm. The mean (FNW) was 35.15 mm in right femurs, while in left femurs was 35.86 mm. The mean (ITW) was 83.94 mm in right femurs, while in left femurs was 59.21 mm. The mean (Q angle) was 132.98 degrees in right femurs, while in left femurs was 133.29 degrees. The mean femoral offset was 39.16 mm in right femurs, while in left femurs was 37.88 mm. The mean length of the femoral neck (LFN) was 40.42 mm in right femurs, while in left femurs was 37.82 mm. So side has effect on (FNAL), (FHW), (FNW), (ITW) and (LFN), but has no effect on (Q angle) and femoral offset.

Table (5) shows the normal variables of the proximal femur: Femoral neck axis length (FNAL), Femoral head width (FHW), Femoral neck width (FNW), Intertrochanteric width (ITW), Q angle, Femoral offset, Length of the femoral neck and length of the femoral shaft according to side of the femur.

Variable	Rt side (60) Mean± SD, Range (mm)	Lt side (40) Mean± SD, Range (mm)	Student t test	P value
FNAL	95.56±4.62,89.3-100.14	92.84±1.64,91.22-94.46	3.57	0.001**
FHW	64.53±18.06,48.58-89.54	50.2±1.09,49.12-51.27	5.01	0.001**
FNW	35.15±1.38,33.25-36.39	35.86±1.33,34.55-37.17	2.55	0.012*
ITW	83.94±4.16,79.35-89.36	59.21±21.56,37.92-80.5	8.67	0.001**
Q angle (degree)	132.98±1.81,131.5-135.5	133.29±3.93,129.4-137.17	0.524	0.601
F offset	39.16±3.34,34.67-42.55	37.88±8.68,29.3-46.45	1.04	0.303
LFN	40.42±3.18,37.2-44.71	37.82±0.63,37.2-38.44	5.1	0.001**
Length	33.65±0.85, 32.67-34.73	36.11±0.84,35.28-36.94	14.21	0.001**

Histogram (4) shows the normal variables of the proximal femur according to side.

4. Discussion

The present study deals with the normal morphometric measurements of the proximal femur in dried bones and among different age groups on

radiographs as well. Also this study evaluates the rule of proximal femur morphometry in determining the risk of Hip fractures in elderly and the adequability of implants used in treatment of these fractures as fixed angle plates and hip prostheses.

As regards the radiological cases, The previous studies focused on the last two age groups, the fourth and the fifth age groups. So When the results of the fifth age group was compared with previous studies addressing different populations on the same age group, we found that as regards HAL, it was 116.2 mm. this result was nearly similar to those Gnudi et al., 2002 **(4)** which was 100.7 mm, Crabtree et al., 2002 **(5)** which was 100.3 mm, Bergot et al., 2002 **(6)** which was 100.5 mm**,** Pulkkinen et al. 2004 **(7)** which was 100.4 mm**,** Irdesel and Ari, 2006 **(8)** which was 100.8 mm but differed from that of Gomez et al. 2000 **(9)** which was 60.3 mm. The FNAL was 106.69 mm. this result was nearly similar to that of Irdesel and Ari, 2006 **(8)** which was 100.1 mm but differed from that

of Bergot et al., 2002 **(6)** which was 90.3 mm, Pulkkinen et al. 2004 **(7)** which was 90 mm. FHW was 53.5 mm. This result was nearly similar to that of Irdesel and Ari, 2006 **(8)** which was 52 mm but differed from that of Pulkkinen et al., 2004 **(7)** which was 43 mm. FNW was 37.95 mm. this result was nearly similar to that of Gomez et al. 2000 **(9)** which was 32 mm, Bergot et al., 2002 **(6)** which was 31 mm, Irdesel and Ari, 2006 **(8)** which was 35 mm but differed from that of Pulkkinen et al., 2004 **(7)** which was 29 mm. ITW was 82.91 mm. this result was nearly similar to that of Irdesel and Ari, 2006 **(8)** which was 84 mm but differed from that of Pulkkinen et al., 2004 **(7)** which was 52 mm. Q angle was 130.3°. This result was nearly similar to that of Gnudi et al., 2002 **(4)** which was 132°, Pulkkinen et al., 2004 **(7)** which was 128.3° and Irdesel and Ari, 2006 **(8)** which was 131.5° but differed from that of Gomez et al., 2000 **(9)** which was 124.6°, Bergot et al., 2002 **(6)** which was 125.6°.

When the results of the fourth age group was compared with that of Robinson Esteves et al., 2011 **(10)**, we found that as regards FNAL, it was 98.66 mm. this result differed from that of Robinson Esteves et al., 2011**(10)** which was 118.3 mm. FNW was 35.34 mm. this result was nearly similar to that of Robinson Esteves et al., 2011 **(10)** which was 39.2 mm. LFN was 39.49 mm. this result was nearly similar to that of Robinson Esteves et al., 2011 **(10)** which was 37.2 mm. Q angle was 130.59 mm. this result was nearly similar to that of Robinson Esteves et al., 2011 **(10)** which was 131.7 mm.

As regards the dried human femurs, it shows sex difference as follows, the Q angle was 132.98°, 133.29° in the right and left sides respectively. This result was nearly similar to that of Eduardo Branco de Sousa et al., 2010 **(11)** which was 132.1°, 131.8°, but differed from those of Mourao & Vasconcellos., 2001 **(12)** which was 111.2°, 114.2°, Igbigbi & Msamati., 2002 **(13)** which was 121.09°, 114° and Silva et al., 2003 **(14)** which was 122.55°, 125.61° Showing particular characteristics in each population studied. Regarding the linear measurements, this study recorded FHW which was 64.53, 50.2 mm in the right and left sides. This result differed from that of Eduardo Branco de Sousa et al., 2010 **(11)** which was 47.1, 46.4 mm. FNW was 35.15, 35.85 mm in the right and left sides respectively. This result was nearly similar to that of Eduardo Branco de Sousa et al., 2010 **(11)** which was 31.1, 30.8 mm, but differed from those of Mourao & Vasconcellos., 2001 **(12)** which was 26.7, 26.3 mm, Igbigbi & Msamati., 2002 **(13)** which was 28.7, 28.3 mm. LFN was 40.42,37.82 mm in the right and left sides. This result differed from those of Mourao & Vasconcellos., 2001 **(12)** which was 24.9, 24.3 mm, Igbigbi & Msamati., 2002 **(13)**

which was 26.9, 26.4mm, Saliva et al., 2003 **(14)** which was 22.3, 23.5mm, Eduardo Branco de Sousa et al., 2010 **(11)** which was 30.1, 30.5 mm in the right and left sides. The femoral offset was 39.16, 37.88 mm in the right and left sides. This result was nearly similar to that of Eduardo Branco de Sousa et al., 2010 **(11)** which was 42.6, 42 mm.

As regards the sex difference, the cervicodiaphyseal angle (Q angle) was 134.72 °, 130.67° in males and females respectively. This result was nearly similar to that of Tahir et al., 2001 **(15)** which was 136.7°, 126.65°, But this result differed from that of Igbigbi & Msamati., 2002 **(13)** which was 140.2 °, 125.7°. FHW was 62.41, 53.37 mm in males and females. This result differed from that of Duthie et al., 1998 **(16)** which was 50.2, 45.2 mm. FNW was 34.73, 36.5 mm in males and females. This result was nearly similar to that of Duthie et al., 1998 **(16)** which was 35.8, 32.1 mm. LFN was 40.42, 37.82 mm in males and females. This result differed from that of Duthie et al., 1998 **(16)** which was 32.5, 35 mm.

Conclusion

From this study we conclude that the maximum increase of the proximal femoral measurements occurs between age of 12-40 years. While the cervicodiaphyseal angle (Q angle) showed maximum decrease between age of 1-20 years.

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