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FORECAST OF FEMUR BONE SKELETON WITH ANATOMICAL PARAMETER OF INDIAN POPULATION

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Abstract-

Total hip replacement (THR) is a surgical procedure that replaces a diseased hip joint with artificial bone known as implant. Due to extensive variations in the sizes and shapes of femur bone, a selected commercial hip implant sometimes may not be best-fit to a patient, or even it cannot be applied as geometric discrepancies between the femur and implant. The aim of the study is to develop mathematical approach through which geometry of femur can be obtained by using anthropometric data. From result it was explicit that the measured value and value obtained by means of mathematical model showed authentic correlation in male and female categories. The model was validated by comparing measured value with calculated value and the agreement was found qualitative as coefficient of correlation were more than 0.90 for each category.

Keywords: - Femur bone, Modeling, Anatomical parameter, Hip implant.

I. INTRODUCTION

The anatomical parameters of proximal femur are crucial in design and development of implant for total hip replacement (THR). The use of an appropriate femoral component size is essential to maintain the normal functional range of motion of hip. In addition, a mismatch between the prosthesis size and bone may result in several severe complications such as stress shielding, micromotion and loosening [1,2,3]. It has been demonstrated that using an undersized component will result in implant loosening, whilst an oversize component may cause impingement of the surrounding soft tissues. The use of appropriate component size is therefore crucial to produce long-term success [4,5,6]. The geometric discrepancies between the natural acetabulum and implant can result in painful iliopsoas [7]. Most of these implants were designed and manufactured from the European and North American region which presumably based on the morphology of their respective population. The use of such implants in other regions may not be appropriate as the design may not take into consideration the morphology of the local population, thus affecting long term and short-term outcomes of the surgery [8,9].

Several researchers has been defined importance of hip geometry and derived geometric measurements from DXA (Dual energy X ray absorptiometry) image of hip joint. This include hip axis length, femoral neck length, femoral neck width and neck shaft angle these parameters best for clinical use [10,11,12].

In this study the parameters mainly femoral head diameter, femoral neck diameter, horizontal offset, vertical offset and neck shaft angle are considered for modelling. To avoid post-operative problems and revision surgery, geometry of implant should be perfect with all above five parameters. The anthropometry data like age, height, weight, leg length and waist size are collected to get relationship between femoral head diameter, femoral neck diameter, horizontal offset, vertical offset and neck shaft angle using mathematical model. The aim of the study is to recommend an innovative approach designed for forecast the geometry of femur prior to surgery using mathematical modeling. Modelling is based on the framework of the geometric parameters, will help the surgeon in preplanning THR surgeries.

II. MATERIALS AND METHOD

The study was carried out in Vidarbha region, central part of India, since 2014. The anatomical parameters of 125 (67 Male and 58 Female) subjects were collected. The data like Age (A) in years, Weight (Wt) in Kg, Height (Ht) in Cm, Leg Length (LL) in Cm, and Waist Size (WS) in Cm of patients were recorded at the entry time in hospital for treatment. The data measured were expressed in mean and standard deviation shown in Table I.

TABLE I. SUMMERY OF MEASURED INDEPENDENT PARAMETERS

Parameter	Gender	No. of Observe	Min	Max	Mean	S.D
Age (A)	Male	67	50	70	60	5.5
	Female	58	50	70	60	5.6
Weight (Wt)	Male	67	54	80	67	5.1
	Female	58	51	73	60	4.6
Height (Ht)	Male	67	147	179	163	8.9
	Female	58	141	168	153	7.0
Leg Length (LL)	Male	67	87	99	93	3.1
	Female	58	78	99	89	6.0
Waist Size (WS)	Male	67	80	98	89	4.9
	Female	58	78	101	88	7.0

The measurement of anatomical parameter was carried out from radiographs of hip joint (Fig.1) of same subject which anthropometric data was collected. Few parameters were identified like Femoral Head Diameter (FHD), Femoral Neck Diameter (FND), Neck Shaft Angle (NSA), Horizontal Offset (HO), and Vertical Offset (VO). The data collected was distributed into male and female subjects to decrease the effect of variations. There was noticeable variation in the femoral bone dimensions tabulated in Table II.

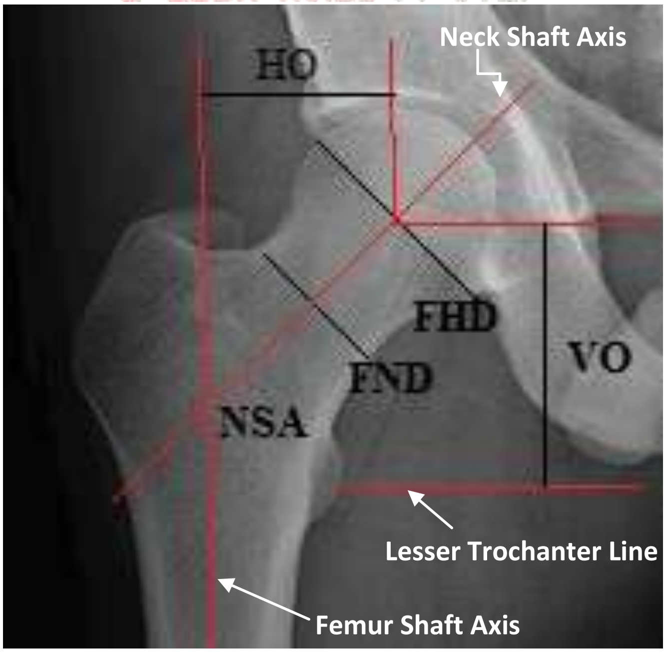


Fig.1. Position of anatomical parameters measured from the radiograph

TABLE II. SUMMERY OF MEASURED DEPENDANT PARAMETERS FORM X - RAYS

Parameter	Gender	Age Group	No. of Observe	Min	Max	Mean	S.D
Femoral head diameter	Male	50 - 70	67	47.71	56.28	52.00	2.32
	Female		58	43.82	50.04	46.53	1.54
Femoral neck diameter	Male	50 - 70	67	31.78	36.55	34.16	1.17
	Female		58	26.71	29.12	27.78	0.66
Horizontal offset	Male	50 - 70	67	41.65	50.21	45.93	2.00
	Female		58	39.60	43.72	41.74	1.06
Vertical offset	Male	50 - 70	67	57.71	70.29	64.00	3.03
	Female		58	53.67	59.46	55.92	1.72
Neck-shaft angle	Male	50 - 70	67	119.32	141.97	130.64	6.87
	Female		58	120.05	137.15	126.91	5.11

The identified parameter like Age, Weight, Height, Leg Length, and Waist Size were recorded as independent parameters and Femoral Head Diameter, Femoral Neck Diameter, Neck Shaft Angle, Horizontal Offset, and Vertical Offset, etc were considered as dependant parameter. A multiple regression analysis was used to find out the relationship between dependent and independent parameters, the equation derived for both male and female to get dependant parameters given below. (Deshmukh T, 2010)

A. Equation for Male

$$FHD = 0.0015[(A)^{0.4111} \times (Wt)^{0.4776} \times (Ht)^{0.6107} \times (LL)^{0.43376} \times (WS)^{0.3789}]$$
$$FND = 0.00396[(A)^{0.367} \times (Wt)^{0.3401} \times (Ht)^{0.4125} \times (LL)^{0.548} \times (WS)^{0.348}]$$
$$HO = 0.00133[(A)^{0.4436} \times (Wt)^{0.3980} \times (Ht)^{0.52047} \times (LL)^{0.5096} \times (WS)^{0.4487}]$$
$$VO = 0.00058[(A)^{0.4549} \times (Wt)^{0.5034} \times (Ht)^{0.5831} \times (LL)^{0.5473} \times (WS)^{0.4908}]$$
$$NSA = 0.000928[(A)^{0.6206} \times (Wt)^{0.61} \times (Ht)^{0.7277} \times (LL)^{0.6295} \times (WS)^{0.043}]$$

B. Equation for Female

$$FHD = 0.001593[(A)^{0.4251} \times (Wt)^{0.3942} \times (Ht)^{0.52632} \times (LL)^{0.4738} \times (WS)^{0.48155}]$$
$$FND = 0.01575[(A)^{0.32901} \times (Wt)^{0.27038} \times (Ht)^{0.43977} \times (LL)^{0.25408} \times (WS)^{0.37232}]$$
$$HO = 0.002654[(A)^{0.29318} \times (Wt)^{0.2889} \times (Ht)^{0.57009} \times (LL)^{0.46415} \times (WS)^{0.51936}]$$
$$VO = 0.000994[(A)^{0.43109} \times (Wt)^{0.40483} \times (Ht)^{0.5562} \times (LL)^{0.51495} \times (WS)^{0.53776}]$$
$$NSA = 0.000028[(A)^{0.7051} \times (Wt)^{0.7065} \times (Ht)^{0.7157} \times (LL)^{0.6761} \times (WS)^{0.649}]$$

III. RESULT

All above equation were used to obtain mean value of FHD, FND, HO, VO and NSA. Table III showed results of mean value of all measured parameters and calculated parameters of all subjects arranged gender wise. The variations in measured and calculated values of all parameters were noted.

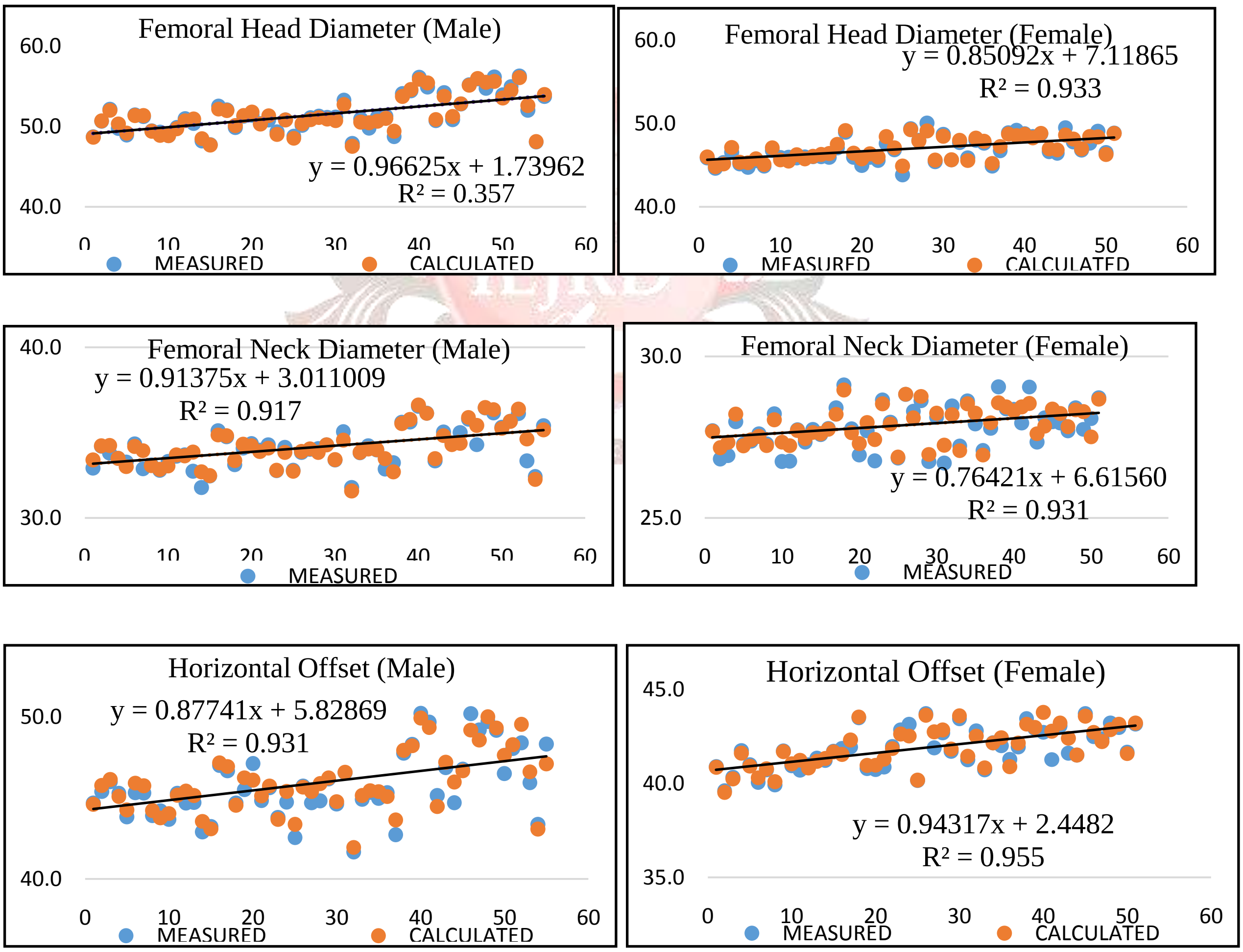
TABLE III. CALCULATED VS MEASURED PARAMETERS (MEAN)

Parameter	Male		Female	
	Calculated Mean	*Measured Mean*	*Calculated Mean*	*Measured Mean*
FHD	51.80	52.00	46.94	46.53
FND	34.10	34.16	27.85	27.78
HO	45.97	45.93	41.82	41.74
VO	63.60	64.00	56.42	55.92
NSA	130.35	130.64	126.91	126.91

Each calculated value and measured value of all five parameters was used to obtain regression line equation and ultimately correlation was derived. Table IV showed all results of regression line and coefficient of correlation, each calculated value of FHD, FND, HO, VO and NSA were compared with measured value and good agreement was found between all parameters. Total ten graphs were obtained for male and female subjects shown in Fig .2. All graphs showed correlation coefficient more than 0.90 for all categories indicating the good relationship between measured and calculated parameters.

TABLE IV. REGRESSION LINE EQUATION AND COEFFICIENT OF CORRELATION

Parameter	Male		Female	
	Regression Line equation	R^2	***Regression Line equation***	R^2
FHD	Y= 0.96625x + 1.73962	0.973	Y= 0.85092x + 7.11865	0.933
FND	Y= 0.91375x + 3.011009	0.917	Y= 0.76421x + 6.61560	0.931
HO	Y= 0.87741x + 5.82869	0.931	Y= 0.94317x + 2.4482	0.955
VO	Y= 0.96507x + 2.19472	0.975	Y= 0.94252x + 3.20652	0.945
NSA	Y= 1.0082x - 1.04108	0.996	Y= 1.11711x – 14.8606	0.943



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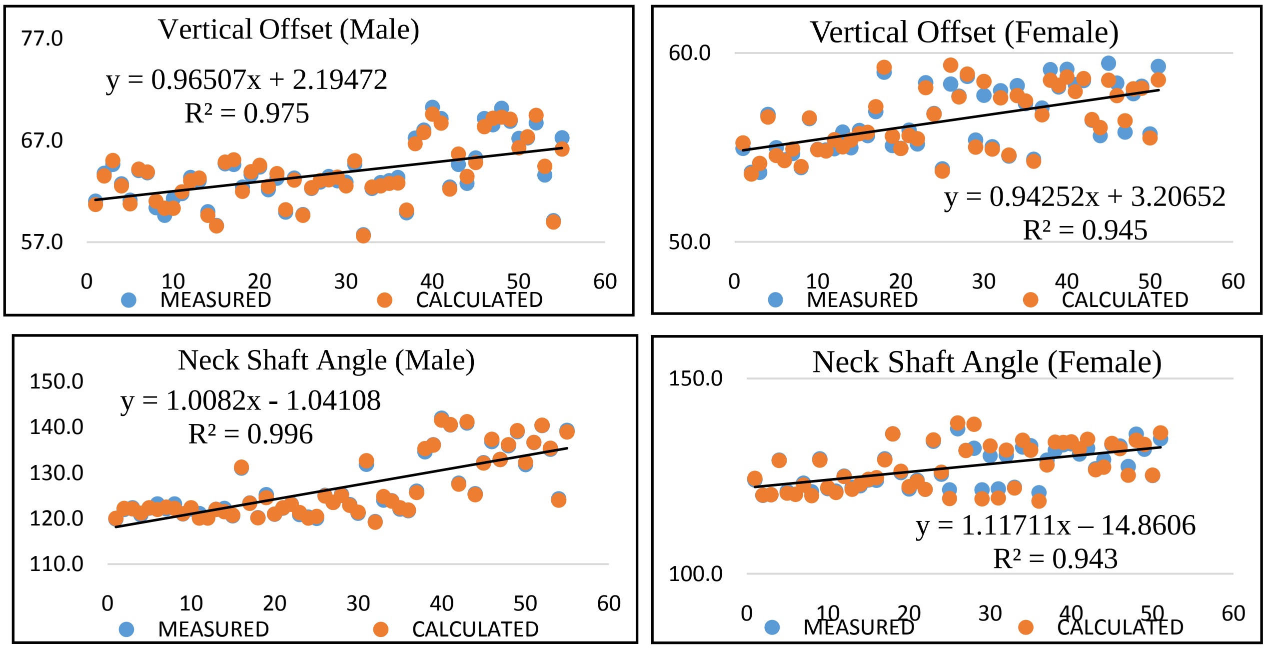

Fig. 2. Coefficient of correlation of measured and calculated parameters for male & female

variation. It is a measure of the degree of fit. When R^2 approaches unity, it results in a better response model and fits the actual data. The square of coefficient of correlation (r) for the above models was found to be more than 0.90 in each case indicating that a high degree of correspondence exists between the measured parameter and calculated parameters.

VI. DISCUSSION

It was exposed that; preoperative understanding of femur geometry is essential for the preparation of surgical procedures and the success of such surgeries depend on good prediction of unknown variable parameters. There was variation in shape and size of human femur bone as per different ethnic groups and geographical locations. After measurement of four anatomical parameters such as femoral head diameter, femoral neck width, femoral neck length and collo-diaphyseal angle a statistical analysis showed no significant differences between left and right femora but significant differences were found between male and female subjects [8]. Also, there were substantial variation in neck shaft angle, vertical offset and shape of the anterior ridge of the acetabulum was found curved, irregular, angular or straight [13,14]. Thus, bone-implant fit is challenging to achieve, there were cases where the selected implant did not exactly fit the morphology of the femur from a population [15,16].

A range of researchers have worked to find out one of the parameters of femur geometry [17,18,19]. The recommended approach for obtaining overall parameters of femur bone was simplest and precise. Hence reduction in cost, lead time and operation time is achieved. Gotze et al. (2002) proved the importance of a suitably matched implant for successful surgery through a custom-made femoral stem [20]. The current approach offered good relation between all parameters and they could be used in the design and development of implants suited for local population as well as assisting in decision making during clinical practices.

V. CONCLUSION

This was innovative approach which provides qualitative agreement and prevents the surgeon from selecting wrong implant, thus lead time and operation time were reduced. Also prevent common complication such as prosthetic loosening and dislocation. In addition to that emphasize the importance of femoral parameters specially the FHD, FND, HO, VO and NSA. The present study will assist and enhance facts for better understand of hip region for the clinicians, orthopaedicians, and radiologists.

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