Journal of Medical Sciences

ISSN 1682-4474

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Journal of Medical Sciences

ISSN 1682-4474
DOI: 10.3923/jms.2019.11.16

Research Article
Standardized Hip Implant by Cluster Analysis of Anthropometry Parameters of Femur

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Abstract

Background and Objective: A range of research told that there is extensive variations in the sizes and shapes of femur bone across different ethnic groups and geographical locations, thus particular bone-implant fit is challenging to achieve. Prosthesis of mismatched sized can caused serious problems for patients. Thus aim of the study was to design standard hip implant based on anatomical parameter of respective population. **Materials and Methods:** Eleven osteological parameter of femoral prosthesis of 125 patient (67 male and 59 female) were evaluated, these eleven parameter were grouped to obtain scatter diagram. Then cluster analysis in SPSS software V25 was carried out by using slink clustering method. **Results:** After studying scatter diagram it was found that 15% population had irregular anatomy then rest of population. So, remaining data put under cluster analysis gives 8 (4 for men and 4 for women) sets of standard anatomical parameter for designing hip implant. **Conclusion:** These eight standard hip implant satisfy 85% population of Vidarbha region.

Key words: Hip implant, standard anatomical parameter, femoral prosthesis, mismatched sized, cluster analysis, Slink method, osteological parameter

Received: September 26, 2018 Accepted: November 20, 2018 Published: December 15, 2018

Citation: Gajanan Damodhar Mandavgade and Tushar Ramkrishna Deshmukh, 2019. Standardized hip implant by cluster analysis of anthropometry parameters of femur. J. Med. Sci., 19: 11-16.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Importance of hip geometry has been well defined in previous studies[1-5]. Due to wide variation in anatomy of femoral prosthesis, it is difficult to achieve precise bone implant fit. Asians have a smaller distal femur size than that of the western population[6,7]. But maximum artificial femoral prosthesis are standardize and manufacture in European and north American region[8] and currently available western orthopaedic implants do not match the dimensions of the proximal femoral of Indian population. The usage of these over-sized and unsuitable implant affect outcome of the surgery reported with problems such as stress shielding, micro-motion and loosening[9-12]. This standard hip implant were not useful for population of Vidarbha region because they were not based on anthropometry of respective population[13].

The variations in dimensions may need to be considered when designing the appropriate implant[14]. To eliminate mismatch between femur and implant and to attain suitable fitment, it was necessary to design a few standard implant based on shape and size of proximal femur of respective population. So, objective of the study was to design standard hip implant based on anatomical parameter of Vidarbha region population.

MATERIALS AND METHODS

Present study was carried out since 2014 in Vidarbha region central part of India. An eleven anatomical parameter of femur were identified from X-ray image of 125 patients, in the age group of 50-70 years. Out of total patients 67 were male and 58 were female. Each X-ray image of 125 patients was processed in RadiAnt DICOM Viewer 4.2.1 software. By means of linear and angular measure tool in software all anatomical parameter of femur were measured. The exact position of each anatomical parameter from where its value was measured shown in Fig. 1 and the measured value of each anatomical parameter designated by alphabets in Fig. 1 exposed in Fig. 2. Following were the anatomical measurements used for study:

- **Femoral head diameter (FHD):** Diameter of femoral head in frontal plane
- **Femoral neck diameter (FND):** Diameter of femoral neck in frontal plane
- **Horizontal offset (HO):** The horizontal distance between the centre of the femoral head and the shaft axis in frontal plane

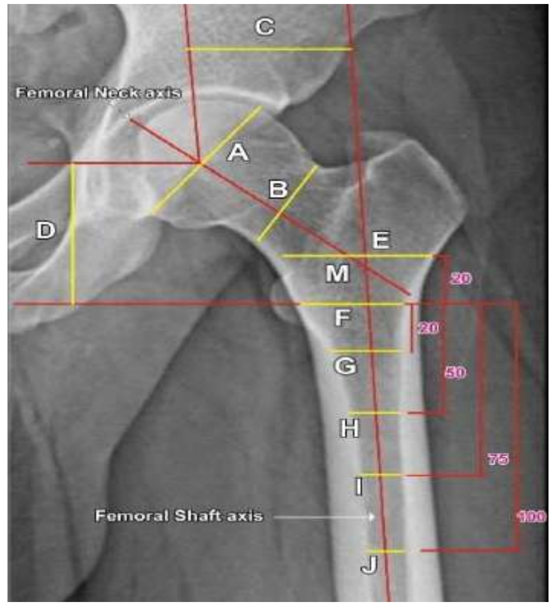

Fig. 1: Anatomical parameter on femur

Fig. 2: Measured value of anatomical parameter on femur

- **Vertical offset (VO):** The vertical distance between the centre of the femoral head and the middle of lesser trochanter level
- **Canal width (CW):** The CW 20 mm above from lesser trochanter at E in frontal plane of femur
- **Canal width (CW):** The CW in frontal plane, passing through the middle of the lesser trochanter
- **Canal width (CW):** The CW 20 mm below from lesser trochanter at G in frontal plane of femur

- **Canal width (CW):** The CW 50 mm below from lesser trochanter at H in frontal plane of femur
- **Canal width (CW):** The CW 75 mm below from lesser trochanter at H in frontal plane of femur
- **Canal width (CW):** The CW 100 mm below from lesser trochanter at J in frontal plane of femur
- **Neck-shaft angle (NSA):** The angle between the shaft axis and the neck axis

Grouping of anatomical parameter: The measured value of anatomical parameter of femur were divided into three groups for prosthesis designing purpose (i) A, B, E, F and G were important for deciding Anterior-Posterior cross section of prosthesis (ii) H, I, J, used for determine distal length and (iii) C, D and M for orientation of neck of the prosthesis.

Finding out dissimilar set of object: Aimed at finding dissimilar set of data a standard deviation of each parameter was calculated and on the basis of standard deviation scatter diagram of each parameter was plot. After examining scatter diagram it was found that some set point were not in range because anatomical parameters of some patients were irregular i.e., there anatomy not in range with rest of patients and they requisite customized hip implant. Such patients were omitted and remaining patient was used for cluster analysis.

Cluster analysis: Romesburg[15] defined cluster analysis is mathematical method, can be used to find out which objects in a set are similar. Cluster analysis has an endless list of user because classification (which object in set are similar and dissimilar) are essential building blocks in field of research. Cluster analysis carried out using following six steps: (1) Obtain data matrix, (2) Standardize data matrix, (3) Calculate resemblance matrix, (4) Implement clustering method, (5) Reposition data and resemblance matrix and (6) Compute cophenetic correlation coefficient.

In existing study IBM SPSS Statistic software (Version 25) was used to execute hierarchical clustering with slink clustering method for four cluster and standard deviation ranging from -1 to 1. A slink clustering method calculate closest members of two cluster. After completing cluster analysis in SPSS software input data was split on basis of fourth cluster.

RESULTS

The database of the measured values of each anatomical parameters for first 10 patients out of 125 patients were presented in Table 1. To find out dissimilar data base total 22 scatter diagram was obtained, few of them given below in Fig. 3 as a sample. After analyzing scatter diagram it was found that 15% patients (In male category 12 patients out of 67 patients and 7 patients out of 59 patients from female) had abnormal anatomy. These patients were omitted and listed in Table 2.

Remaining 85% database of patient was used for cluster analysis. After completing cluster analysis in SPSS software forecast values of each parameter were summarized in Table 3. Total 8 (4 Male and 4 Female) sets of standard anatomical parameters provide standard sizes hip implant designs, which was found suitable for Vidarbha region population.

In this study conventional X-ray technique has been used for understanding the femur bone geometry. The outcome of current study make available eight set of standard anatomical parameter for hip implant design which satisfy maximum population of Vidarbha region. Equally they achieve proper fitment because they were standardize on anthropometry of respective population and reduces chance of revision surgery. It also reduces operating time and achieve successful positioning in hip joint.

DISCUSSION

Surgeon who perform hip replacement surgeries must depend on implant manufacture to provide proper implant

Table 1: Measured anatomical parameter of femur

Parameters	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	H (mm)	I (mm)	J (mm)	M (deg)
1	51.1	34.3	47.0	66.4	52.4	32.1	19.6	13.2	11.5	11.5	131.3
2	51.6	39.5	51.8	61.8	51.1	31.1	20.4	14.3	13.4	12.9	120.3
3	43.7	27.7	46.6	59.0	47.7	30.7	19.8	15.7	15.1	12.0	125.7
4	44.7	31.9	43.5	70.3	41.3	27.8	18.8	15.0	14.4	10.5	134.9
5	40.5	27.1	37.8	48.9	44.4	25.1	18.0	14.0	13.6	11.5	124.2
6	49.6	29.6	47.6	59.6	51.2	29.6	19.2	14.3	13.6	12.3	123.5
7	49.3	36.2	34.9	54.6	49.2	30.7	20.6	12.7	11.6	10.4	141.8
8	51.2	34.1	37.8	53.2	50.5	32.4	22.1	15.7	14.4	13.3	124.3
9	53.8	35.1	44.4	55.0	60.0	33.7	19.4	15.3	14.9	12.2	124.0
10	45.4	28.3	40.1	41.8	51.0	34.4	23.4	18.3	15.0	14.9	132.0

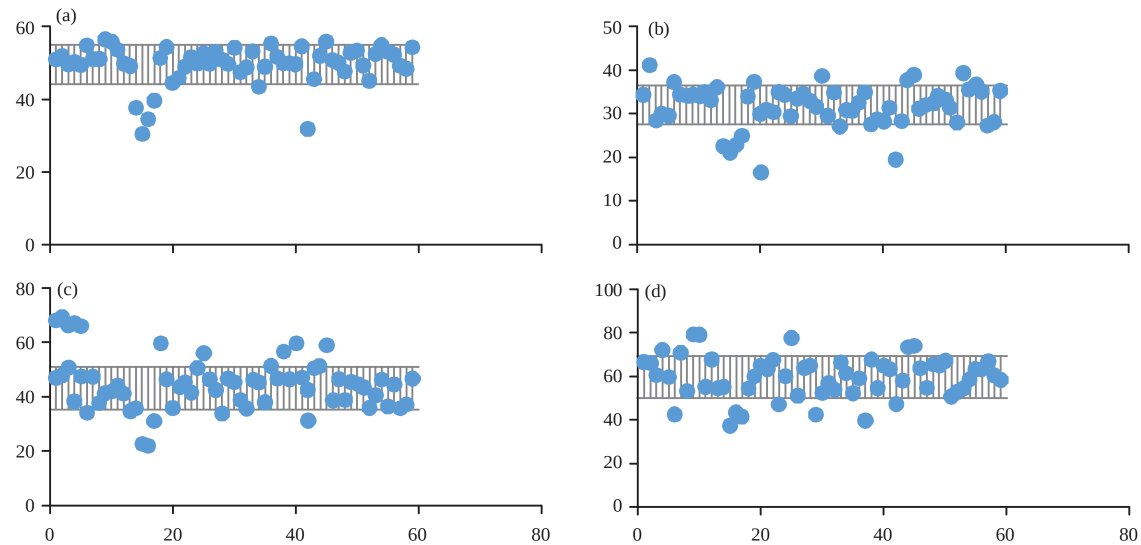

Fig. 3(a-d): Dissimiam of measured anatomical parameter as per, (a) Femoral head diameter, (b) Femoral neck diameter, (c) Horizontal offset and (d) Vertical offset

Table 2: Irregular anatomical parameter of femur

	Patients having irregular anatomical parameters																		
	Male												Female						
AP	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7
A (mm)		58	58	38	31	35	40	32	59					40	53	53			34
B (mm)	37			23	21	23	25	20	39					23	34	33	23	32	
C (mm)	34				23	22	31	31	59				46	30		33			30
D (mm)	43	79	79		38	44	41	47	74	40			37		66	64		43	37
E (mm)	37	56		36	35	38	40	36		57		57		34	37		54		
F (mm)	18	40	40	22	17		21	17			42	42		21			36	39	22
G (mm)	11	29	29		8	15	14	12		30	32	27		15			28	32	15
H (mm)	11	20	19	11	6	9	10	10		20	28	21		12			20	22	10
I (mm)		17		10	5	7	9	9		18	25	19		11			17	22	9
J (mm)				9	6	7	9	8		18	25			9.5				20	7
M (deg)	118					142			117				118			141			

Table 3: Anatomical parameter for designing standard implant

		Male				Female			
AP	N	1	2	3	4	1	2	3	4
A (mm)	106	55.7	49.5	47.1	53.4	51.0	45.7	43.1	48.4
B (mm)	106	36.5	34.0	31.8	35.2	29.1	27.7	26.0	26.9
C (mm)	106	50.2	43.6	40.6	47.6	43.9	41.5	39.6	43.1
D (mm)	106	70.3	61.2	56.7	65.8	59.9	57.2	52.7	54.9
E (mm)	106	51.0	47.4	43.4	54.4	58.3	54.1	44.6	49.8
F (mm)	106	32.3	30.3	27.8	34.8	38.1	35.3	29.0	32.4
G (mm)	106	22.3	21.2	19.4	23.4	26.5	24.3	20.2	22.3
H (mm)	106	16.2	15.1	13.8	16.9	19.8	18.9	15.1	17.4
I (mm)	106	14.3	13.3	12.2	15.2	17.2	16.4	13.1	14.8
J (mm)	106	12.3	11.5	10.5	13.2	14.8	12.1	11.4	13.6
M (deg)	106	141.0	126.0	120.0	133.0	135.5	130.5	120.0	125.0

sized but there were limitation in design of implant. The proposed approach for standardize a hip implant was simplest and quite accurate. The proposed implant improve longer term outcome and clinical functionality for Vidarbha region population by reducing loosening rate and complication rate. There was inconsistency in measurement of parameter. Thus it was challenging to attain specific bone implant fit. Statistical analysis showed no significant differences between left and right femora but significant differences were found between male and female subjects[8,16]. Also, the neck shaft angle varies[17] from 125-132°. It was noted that Nigerians were taller than average Indians so their femoral heads were bigger than that of Indians[18]. The femoral neck diameter and neck shaft angle for Hong Kong Chinese population were small when compared with their western counterpart[19]. The undersized and overhanging hip implant could lead to replace soft tissue and patella[20]. Improper choice of implant could create serious problem for patient in long period[21,22]. There is a deficiency of literature relating to the effect of improperly sized implants on patient outcome.

However, forecast result are based on measured anthropometric data, it is some time subject to variation by the system utilized. This study will help medical practitioner in particular and common population in general.

SIGNIFICANCE STATEMENT

It was disclosed that the current finding (eight standard hip implant) can provide suitable fitment to the majority of the population. It is innovative step and more purposeful to prevent general complications like prosthetic loosening and dislocation. While a small percentage of population will always be requiring the customized prosthesis for exact fitment. The current outcome will also assist and enhance facts of hip region for the clinicians or thopaedicians and radiologists.

CONCLUSION

To validate the need of designing a hip implant based on particular location, an effort has been made for collection of data (Anatomical Parameter) of vidhrabha region population and scatter diagram is formed on basis of standard deviation. After examine a scatter diagram it found that 15% population had irregular shape of hip prosthesis. Cluster analysis was carried out on remaining dataset, which offered 8 set of standard anatomical parameter, on this basis 8 standard hip implant could design for population of the study region. These 8 set of standard hip implant serve 85% of population.

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