"MORPHOMETRIC ANALYSIS OF THE DRY ADULT HUMAN RADIUS BONE: AN OBSERVATIONAL STUDY"

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LIST OF ABBREVIATIONS

%	Percentage
&	And
C	Cervical
C.I.	Confidence Interval
cm	Centimeter
DRUJ	Distal Radio Ulnar Joint
FOOSH	Fall On Outstretched Hand
GCT	Giant Cell Tumor
mm	Millimeter
No.	Number
NS	Not significant
P	Level of significance
S	Significant
S. No.	Serial number
S.D.	Standard Deviation
T	Thoracic
TFCC	Triangular Fibro Cartilage Complex

ABSTRACT

Background :

Radius is one of the two constituent bones of the forearm of human body which participates in the formation of important joints of the superior extremity and their movements. It is the weight transmitting bone and is frequently fractured, in isolation or accompanying the ulna. It can be fractured or dislocated due to various reasons which can be traumatic, pathological, environmental etc. Incidence and prevalence of such fractures are increasing day by day. Thorough comprehension of the morphometry of radius bone is essential for the timely and effective management as well as treatment of these conditions so that normal functioning of the upper limb is not hampered.

Aims & Objectives :

1. To measure dimensions of the proximal end, distal end & the shaft of the dry adult human radius bone.
2. To collate these dimensions between the right-sided & left-sided radius bones.

Materials & methods :

300 dry adult human radius bones (155 left-sided and 145 right-sided) of anonymous sex, age & race, collected from the Department of Anatomy, KAHER's J. N. Medical College, Belagavi, Karnataka, India, were systematically investigated and the data was then analyzed to obtain the results.

Results:

Mean length of the radius bones was 23.78 ± 1.88 cm. Mean length of the head of the radius bones was 9.47 ± 1.49 mm. Mean diameter of the head of the radius

bones was 19.92 ± 2.03 mm. Mean circumference of the head of the radius bones was 6.42 ± 0.63 cm. Mean circumference of the neck of the radius bones was 4.21 ± 0.52 cm. Mean length of the radial tuberosity of the radius bones was 25.39 ± 4.54 mm. Mean length of ulnar notch of radius bones was 6.22 ± 1.6 mm. Mean width of ulnar notch of radius bones was 15.12 ± 1.52 mm. Mean distance between radial head and radial tuberosity in the bone was 12.48 ± 2.59 mm. Shape of the head of radius (overall) was found to be circular in 66.1 % and oval in 33.9 % of the radius bones. All these values were obtained irrespective of the side of radius bone.

For two parameters, statistically significant difference was obtained between the values for both sides of the bone.

Conclusion:

Studies done in different geographic areas and population have shown an extensively varied range of values for various parameters. As a matter of fact, for certain selected parameters, statistically significant difference was found between the values on the basis of laterality.

Thus, an utmost care and precision is required while treating or prosthesis making in order to avoid untoward outcomes and the ultimate goal of maximum functionality is achieved. This study strives to underline this need for precision by highlighting this varied range of parameters in the regional population.

Keywords :

Digital vernier caliper ; Distal radius ; Fracture ; Morphometric; Osteo-metric board ; Prosthesis ; Proximal radius; Radial head; Radius

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INTRODUCTION

Two long bones, radius and ulna, participate to form the skeleton of forearm in human body.[1] Radius is the lateral component.[2] It is a pre-axial bone which corresponds to the tibia, which is the bone present medially in leg.[1] It has an expanded proximal end, a much broader distal end and a shaft which widens rapidly towards its distal end.[3]

Proximal end of the radius :

It includes :

1. Head,
2. Neck,
3. Tuberosity. [4]

Head of the radius bone :

Its shape is disc-like. It has a shallow cup at its proximal surface for linking with the humeral capitulum. Its smooth peripheral surface associates with the ulnar notch. On stretched elbow, radial-head can be intuited on the postero-lateral segment of it.[3]

Neck :

Neck, the circumferential constriction immediately beneath the head, overhangs it.[3]

Radial tuberosity :

It is located distal to the neck's medial part. Its usually rough at the back and smooth in the front.[3]

Radial shaft :

Laterally, it is convex. In the middle third, the cross-section is triangular.[3]

Anterior-border :

The superior part is oblique which slopes downhill and sideways from the inferior limit of radial-tuberosity. Straight inferior part of the border stretches out as a prominent ridge in the distal fourth of the shaft, where it continues as the anterior border of styloid process. The radial-head of flexor digitorum superficialis derives from the superior oblique border, whereas the inferior vertical ridge connects to the adjacent end of extensor-retinaculum.[1]

Posterior-border :

It is distinct in the middle 1/3rd of the shaft only. Further up, it courses uphill and on medial aspect, reaching the rear inferior part of tuberosity of radius it forms the posterior oblique line.[5]

Inter-osseous border (Medial) and medial surface :

This is the sharpest border, excluding two zones : proximally, adjacent to tuberosity, and distally, where it outlines the rear edge of a tiny, extended, three-sided region, proximal to the notch for ulnar-head. Medial surface of shaft is shaped by these two areas. The strong inter-osseous membrane is affixed to the distal 3/4th of the shaft of radius, and creates a connection between the radius and ulna bone.[3]

Anterior surface :

It is flanked by the anterior edge and inter-osseous edge and is somewhat curved in.[1] Neighboring the middle of shaft, is sited the foramen and canal for the nutrient artery (directed proximally). Anterior interosseous artery branches off as the nutrient artery to radius.[5]

Posterior surface :

It is localized amid the inter-osseous and posterior rims. Middle-third of this surface gives origin to the muscle – Abductor pollicis longus.[5]

Lateral surface :

It is situated sandwiched between the anterior edge and the posterior edge. Supinator muscle is attached at superior broader part of this surface with deep part of radial nerve (posterior interosseous nerve) passing in between its superficial and deep fibers. Pronator teres muscle is attached on the coarse part of most curved mid-portion.[5]

Distal radius :

It is the widest part which presents five surfaces.[5]

Anterior surface :

It has a prominent thick ridge to which attaches the palmar radio-carpal ligament of the wrist joint. This thick ridge is palpable against the overlying tendons. Radial artery pulsation is perceived against this surface, distal to the pronator quadratus.[1]

Posterior-surface :

A tubercle located dorsally –'Lister's tubercle' is demonstrable. It showcases three tubercles- one lateral to the dorsal tubercle and two medial to it. The lateral groove is broad and accommodates the tendons of extensor carpi radialis longus along with extensor carpi radialis brevis, more medially. Tendons of extensor digitorum and extensor indices passes past the groove, medial to the extensor pollicis longus.[1]

Lateral-surface :

It protrudes as the radial styloid process (situated distally) which is longer than that of the ulna.[4] Tendons of extensor pollicis brevis as well as abductor pollicis longus crosses it. Brachioradialis is joined with the bottom & radial collateral ligament of radio-carpal joint to the apex of styloid-process.[5]

Medial-surface :

It offers a notch to fit together with the head of ulna bone.[6] Inferior margin of this 'Ulnar-notch' provides attachment to the articular-disc of lower joint involving radius and ulna. The junction amidst ulnar-notch and carpal articular-surface provides attachment to the bottom of three-cornered articular-disc of lower joint amid radius and ulna, the apex of it fixes onto a dip amid lower articular-surface of the ulnar-head and its styloid process. Hence, ulna is omitted from the establishment of wrist joint.[1]

Inferior surface :

It offers a trilateral area for connection with scaphoid laterally and a medial four-cornered area for the lunate (lateral segment).[5]

Radius contributes in establishment of some noteworthy joints of the upper limb like, radio-ulnar joints (proximal & distal), humero-radial joint, wrist joint, which helps in abundant movements of the elbow, forearm & wrist.[1,7] Movements of antebrachium like pronation-supination is necessitated by an arboreal life. [8,9]

An in-depth comprehension of the dimensions of human radius bone & its anatomy is indispensable to attain the greatest possible positive outcomes in reconstruction of the impaired part, rehabilitation of the patient or the prosthesis creation and to abate the after-effects of any surgical procedure done (orthopedic /oncologic).[10,11]

This study will be worthwhile for the orthopedic surgeons, onco-surgeons, physiotherapists, radiologists, clinicians, prosthetists and also for the forensic experts in medico-legal case investigations and archaeologists.[10,12]

Radius bone is fundamental for the supination-pronation movements of the antebrachium, which is the souvenir of human evolution. It is also the weight transmitting bone and is significant for other movements of the upper limb as well. In view of that, more exploration is demanded for this bone as the existing data is disappointing and it can be probed more for the benefit of the society, in general.

So, the present research work is an effort to augment the existing data regarding the radius bone morphometry.

AIMS & OBJECTIVES

AIM :

To appraise the morphometric measurements of the dry adult human radius bone in Belagavi region of Karnataka, India.

OBJECTIVES :

1. To measure dimensions of the proximal end, distal end & the shaft of the dry adult human radius bone.

2. To collate these dimensions between the right-sided & left-sided radius bones.

REVIEW OF LITERATURE

Introduction to the skeletal system :

Bones and cartilages form the skeletal basis of body. They comprise of dedicated connective tissue (Sclerous) that can withstand weight without bending and has substantial tensile forte. [13]

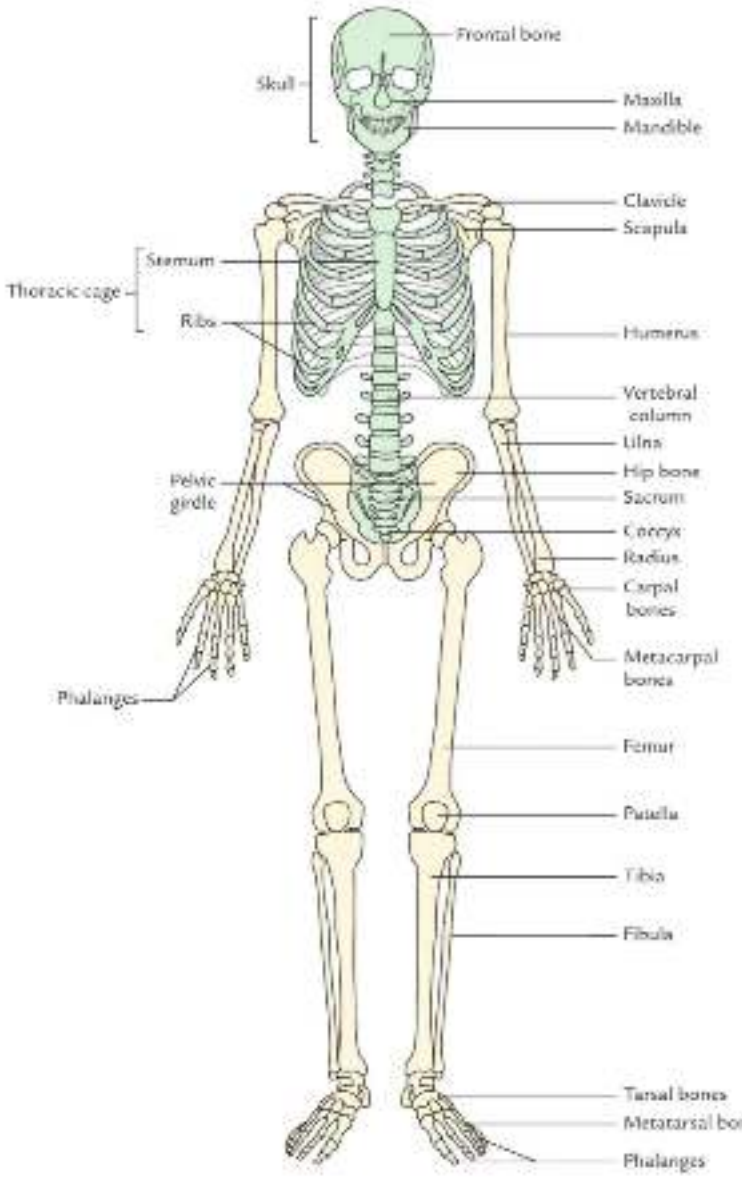
The bony skeleton is segregated into two shares. The Axial skeleton involves bones as well as cartilages which lie in proximity of the central axis of body. It comprises of - skull, rib-cage etc. The Appendicular skeleton entails bones of the superior extremities, inferior extremities and bony girdles which anchor these extremities to the axial skeleton & is symmetrical on both sides. It includes the bones of both girdles (pectoral and pelvic) & both limbs (upper and lower).[13]

Each superior extremity encompasses the 'humerus' bone in the brachium; 'radius' and 'ulna' in antebrachium; the 'carpals', the 'metacarpals' and the 'phalanges' in the hand.[13]

Radius is a long bone of the forearm which is situated lateral to the ulna. Although it is shorter than ulna in length, it contributes to the establishment of the wrist joint. It also partakes in configuring several significant joints of the upper limb thereby playing a key role in the movements.[4,14]

Joint is a connection amid two or more bones and cartilages. It is a stratagem to permit numerous varieties of movements. Bones accompanied by ligaments and muscles are the factors which sustain the stability of a joint. Insufficient backing by ligaments and muscles or the substandard shape of articular surfaces leads to

dislocation of a joint. Fracture is a complete or partial disruption in the continuity of a bone produced due to trauma, overuse or ailments that weaken bones.[13] Factors restricting the span of movements are the shape of articulating bones, tension of the ligaments, tension of antagonistic muscles and the approximation of the soft parts .[15]



Schematic representation of human skeleton: The Axial skeleton is highlighted in green color.

(Courtesy : General anatomy with systemic anatomy, radiological anatomy, medical genetics. 3rd Edition by Vishram Singh, Page no.66. [13])

Evolution :

Ontogeny of the antebrachium illustrates evident changes. It transformed the upper limb and hence the forearm in a fashion which benefits the human species in its survival and to maintain its domination in the living world.

In majority of the Crossopterygians, the internal skeleton contains a series of axial bones (humerus, ulna) from which develop a preaxial (anterior) series of radial bones (radius) etc. The appendicular musculature passes into the base of fin to incorporate few of the proximal skeletal constituents, creating a fleshy basal lobe. Such modification appears in lungfishes and in some fossil crossopterygians, where an elongated central axis is flaunted with postaxial plus preaxial radials.[16]

Along with the paired fins, majority of fishes have unpaired (median) fins, which during swimming stabilizes their body. Uninterrupted continuous folds (dorsal and ventral) shaped by the median fins (round the tip of the tail) are present in immature fishes while in adults, the median fins characteristically comprise one or two dorsals, an anal fin (behind the vent) and a caudal fin. Dorsals can be infrequently reduced in number or absent or manifest in series. The anal fin may disappear, specifically in bottom – dwellers, for instance, in rays. Median fins comprise of the skeleton comparable to that of paired ones, having basalia and radialia set in the base, trailed by dermal fin rays. Radialia in dorsal fins are lean rods that develop in the median dorsal connective tissue septum just higher up from extended neural-spines.[16]

All tetrapod extremities, are developed in accordance with a solitary architectural strategy, regardless of some superficial variations as legs, wings ,arms, and flippers. The generalized tetrapod appendage is pentadactyl and also involves five

regions. Modifications include mainly the loss of digits and associated loss or union of related metacarpals and carpals, infrequently radius or ulna. The limbs in primitive tetrapods were petite and stout, and were pointed horizontally and centrifugally at 90º to the vertical axis of body. This configuration continues today amongst tailed amphibians and certain primitive reptiles. Largely, in reptiles and mammals, an alternation of the appendage towards the body occurs with the purpose of attaining the long axis of the femur and humerus more closely in alignment with the vertical axis of body. To a noticeable extent, thigh and knee are pointed cephalad, however the superior arm may pass relatively caudalad, with the elbow turned backwards. Positioning of the limbs in such fashion offers better support for the weight of the body and facilitates amplified agility.[16]

Some tetrapods have lost one or both sets of appendages. Among amphibians, caecilians are entirely limbless, and sirens are devoid of posterior appendages. Snakes and snake-like lizards are generally limbless; though, pythons, boa constrictors, and a handful lizards have only hind limbs. One lizard (Chirotes) has only the forelimbs. Amongst birds, a small number of ratites are deprived of the fore-appendages. Cetaceans and sirenians in mammals have absence of hind limbs. [16]

In quite a number of the foregoing occasions, where a limb is absent, the embryonic limb-bud surfaces momentarily. Skeleton of forelimbs and the corresponding bones of tetrapods are essentially alike in all classes, and disparities are comparatively negligeable, taking into consideration the basic architectural design. [16]

In the antebrachium, two bone, radius and ulna are present. Ulna is fused with the radius in some ungulates and a radio-ulna arises in frogs. A crescent-shaped notch

in the ulna (at elbow joint) accepts humerus (distal end) apart from few lower forms, and an olecranon process protrudes higher up the notch, averting the elbow from bending in two directions. Radius and ulna are united by an inter-osseus ligament, which occasionally, may ossify. In mammals, the radius partly traverses the ulna to a medial location at its distal end and is generally eternally fixed in this position. In man, the radius may be switched to a lateral position. Supination and pronation will demonstrate the autonomous movement of the radius, in human.[16]

Laura Perez-Criado*, Antonio Rosas investigated twelve fragmented forelimb components (counting ulna and radius) of Homo neanderthalensis, retrieved from the site - El Sidr (Asturias, Spain), relatively, by means of 3-D geometric and conventional morphometrics.[17] In the Neanderthals radius, a longer length of the neck (primitive), placement of the radial-tubercle on medial aspect (primitive-secondarily), and a bowed shaft (primitive-secondarily), were noted. Structurally, in the upper limb, three entities of evolutionary modifications were observed :

i. Olecranon & its fossa,

ii. Coronoid-radius-neck complex,

iii. Radial-tubercle & radial-shaft. [17]

Even though, the radius and ulna have an intimate structural association to adjacent bones along with connection via the inter-osseous membrane, each bone demonstrates distinct prototype for evolution, from a phylogenetic viewpoint. Few features of ulna and radius, have developed in a mosaic style, offering the morphologies that explains the Neanderthal fore-arms.[17]

Embryology :

Entire bone is originated from the mesoderm. “Ossification” is the term given to the process of formation of bone.[18] In a good number of the sections of embryo, formation of a cartilaginous prototype paves the track for the development of bone trailed by the subsequent replacement of cartilage with bone. This sort of bone development is termed as “Endochondral ossification” and the bones created are thus called “The Cartilage bones”. If the formation of bone is not preceded by the cartilaginous-model establishment and is set right into a fibrous membrane, it is termed “Intra-membranous ossification” and such bones are termed as “The Membrane bones”.[19]

Each limb bone (counting the girdle) is result of endochondral ossification, except for the clavicle (membrane bone). At the commencement of 2nd month of intra-uterine life, the limb buds come into existence. They are paddle-shaped extensions that appear from the lateral wall of embryo.[20] Each bud is a bulk of mesenchyme (derived from the lateral plate mesoderm, parietal layer) roofed by ectoderm from which emerges bones, connective tissue and few blood vessels. Musculature of the limbs is derivative of myotomes of somites which travel up to here.[19]

Forelimb buds emerge slightly prior to the hindlimb buds.[21] Further, constrictions develop that segments the forelimb bud into brachium, ante-brachium and manus. Shortly, the outline of digits appears on the hand and the digits separate from one another by inter-digital cell death. Analogous alterations take place in the hindlimb also. These mesenchymal cells of buds develop cartilaginous models while growing. They ossify consequently to produce the limb bones.[19]

Initially, the limb buds are pointed forwards and lateral to the body of embryo. Each bud is now having a preaxial / cranial and a postaxial / caudal border. On the preaxial border develops – 1. Thumb, 2. Great toe .[19]

Radius is pre-axial bone of forearm. With further growth, fore-limb adducts to the body sideways and hence the initial ventral surface constitutes the anterior surface of arm, fore-arm and the hand.[19,22]

The forelimb bud results from that share of the body wall which belongs to C4- T1 and T2 segments. Thus, its innervation is by the corresponding spinal nerves.[19]

Limb axes (3 in number) are defined by the 3 centers in the limb-bud :

1. *Apical-ectodermal-ridge (A.E.R)* : It is crucial for the development of limb-bud as it establishes proximal and distal.

2. *Zone of polarizing-activity (Z.P.A)* : It concludes from cranial towards caudal.

3. Ectoderm (*Dorsal as well as ventral)* : Establishes the axes (dorsal along with ventral).[19]

Radius alone, aided by the articular disc of lower joint between radius and ulna, take part in the configuration of radio-carpal joint. It is the weight-transmitting bone and is frequently fractured due to F.O.O.S.H (fall on outstretched hand). Fractures of shafts of both forearm bones together, is fairly common. Fracture of any of these two bone is probably accompanied with dislocation of the proximate joint, since there exists a strong connection between them by the inter-osseous membrane.[4,23]

There is a noteworthy rise in the number of cases of injury to the elbow/ wrist joint, thereby increasing the count of cases of fractures in several parts of radius bone, tendon ruptures etc.[24–27] The conformation of the distal biceps tendon and radial-tuberosity is significant in the pathophysiology of tendon-rupture, in addition to surgical restoration.[28] In adolescents, the frequent fracture to be identified is the fracture of distal part of radius bone (8-15% of entire upper extremity fractures).[29,30] Sports-related fractures shared 20.1% while fall from height constitutes 49 % of them.[31] Fractures or dislocation of the bones are quite common now a days due to road traffic accidents, direct injury, fall, pathology (osteoporosis, malignancy etc.), sports injury and so on.[12]

"Osteoporosis" is a systemic skeletal ailment that incorporates depleted mass of bone and micro-architectural depreciation of bony tissue.[32] Forearm fractures are the most regular osteoporotic fracture. They are significant forecasters of hip fractures. The fracture ratios in postmenopausal women particularly living in urban than in rural areas are pretty higher.[33] Traditionally, it is believed that osteoporotic-fractures are largely spotted in distal segment of the radius apart from the proximal segment of femur and humerus and the thoraco-lumbar region of the spine. Approximately 30% males, 66% females and 70% of in-patient fractures are possibly 'osteoporotic' . [34,35]

Inferior end fractures in the radius are uniformly shared by both the genders in 35 to 44 years of age but, while in men, the frequency stayed fairly constant, in women it escalated to almost ten times high in age group 65 years and more .[36,37]

Substantial rise in the instances of malignancy heads to the internal bone damage. Distal segment of the radius bone is 3rd most-frequent site of Giant cell

tumor (G.C.T) next to femur (distal segment) and proximal part of tibia.[38] About, 10% cases of G.C.T include distal segment of radius. Restoration of the radio-carpal joint subsequent to 'En-bloc-resection' of distal-segment of radius stays taxing for reason of distinguished practical requirements, inadequate adjacent soft-tissue and bone-mass along with propinquity of crucial nerves as well as tendons. Damage to these joints affects their stability, thereby hindering the activities .[39,40]

Fracture healing is an indispensably significant clinical experience for fracture-patients and for concerned clinicians. The medical appraisal of fracture-healing is centered on both clinical as well as radiographic findings. Risk considerations for tardy union and non-union comprise 'patient-dependent' aspects such as progressive age, health co-morbidities, non-steroidal anti-inflammatory (NSAIDs) usage, several inherited conditions, ailments of metabolism, smoking and dietary deficits. 'Patient-independent' aspects take account of fracture-pattern, site, and dislodgment, gravity of soft-tissue damage, extent of bony damage, quality of invasive treatment and infection incidence. [41–43]

Non-union of the fractured segments are challenging to resolve and develop a tremendous financial pressure. All approaches that aid to lessen healing-time with quicker recommencement to work and routine not only upgrade medical aftermath, they support to cut the monetary load for patients with fracture and its non-union as well.[41,44] Surgical treatment intends to inhibit the cross-union between the two forearm bones, in order to preserve the actions of pronation-supination. [1]

Quite a few reports linked reduction of the radius bone length with soreness, unsteadiness and limited forearm movements (like pronation-supination), affirming that length was the imperative feature disturbing functional consequence. A few

authors proved that radial-shortening grounds an amplified pressure in the 'distal radio-ulnar joint' (DRUJ) and an alteration in hub of pressure inside the sigmoid-notch. It is revealed by diminution of 'grip-strength' as well as kinesis of DRUJ.[45,46]

The Triangular fibrocartilage complex (TFCC), comprising fibers positioned superficially and deep, is the 'chief-stabilizer' of DRUJ. Numerous reports established that those superficial fibers which are placed dorsally, tauten while pronating, in the same manner as deep palmar fibers and vice-versa. Thus, the proportional reduction in pronation as well as supination is correlated to inadequate TFCC reconstruction. [39,47,48]

Sex-determination, age-estimation, stature-reconstruction, identification of anonymous bodily remains or bodies or skeletal remains can be achieved by various anthropometric techniques using a bone as the probe.[49] The standards of anthropometry varies with population.[50] Dimensions of anthropometric elements of elongated bones can be employed for determination of sex and prediction of height.[51] A study done by Pal DC , Mandal D, Datta AK in West Bengal state of India showed that the stature of a living individual can be estimated by means of the radial-length.[52]

Few researches have been conducted on the radius bone morphometry. Rayna et al (2018) carried out a study on the morphometry of radius bone (both proximal and distal parts) at Saveetha Medical College, Chennai, T.N. , India. They studied total of 160 bones (80 each side).According to their study results, average length of the radius bone, medially was 22.7 cm & laterally 23.7 cm, average radial-head circumference was 6.3 cm, and that of the neck was 4.64 cm. The mean medial and lateral length of the radial head were 0.67 cm and 0.32 cm respectively. Length of the neck was 0.75 cm and that of tuberosity was 3.36 cm. Average value of the width of the notch of

ulna was 1.41 cm and length of it was 0.30 and 0.62 cm on anterior and posterior aspect respectively. Radial head shape was mostly circular (77.5 % bones).They also found 18.75 % elliptical and 3.75 % of irregular shape.[12]

In a study done by Gupta et al (2015) at Kasturba Medical College, Manipal, India, using 23 right and 27 left sided radius bones ,the mean values of the radial length as 23.5 cm, radial head height at the medial end as 0.9 cm and lateral end as 0.75 cm, diameter of the radial head transversely as 1.85 cm and anteroposterior length of radius as 1.91 cm respectively, were obtained. Most frequent radial-head shape was circular - 64 % radii. They found insignificant correlation in all parameters of radius bone which they studied (both right & left sides,) as the $p > 0.05$.[53]

Research was conducted by Ethiraj et al (2019) at M S Ramaiah Medical College, Bangalore, Karnataka (India). They explored 60 (23 left sided and 37 right sided) radius bones and obtained the following conclusions. The average radial-length was 24.35 ± 17.22 cm (right) and 23.62 ± 16.89 cm (left). 65 % bones were having round head and rest had oval. The mean length of radial tuberosity was 2.23 ± 0.21 cm in right-side & 2.33 ± 0.29 cm for the left-sided radius bone and they observed the values as 1.32 ± 0.22 cm for right side and 1.26 ± 0.27 cm for the left-sided radius bone for the length of the radial neck. They also studied the ridges on bicipital tuberosity and found single ridge in majority of radii (88.3 %) and rest were having bifid ridge. They could not establish a significant correlation between the values of right and left sided radii .[24]

Singh A and Singh A (2019) conducted a cross sectional study for three months using 106 dry human radii acquired from the department of Anatomy and Forensic medicine, Rohilkhand Medical College & Hospital, Bareilly, U.P.

Anatomical dimensions were executed on these bones using a digital Vernier caliper with accuracy = 0.01 mm. They observed the values 7.99 ± 1.39 mm for right-sided, 9.57 ± 1.40 mm for left-sided and 8.65 ± 1.55 mm as the overall mean length. They found significant difference amid the values of medial height (p=0.001), ventral curve thickness (p=0.009) and of dorsal curve thickness (p=0.001) of both sides of radius bone, where the $p \leq 0.05$.[54]

Shastry et al (2018) performed research on 142 dry cadaveric adult radii at St John's Medical College, Bangalore, Karnataka (India). They studied dimensions of radial-head considering prevention of postoperative complications after prosthesis replacement. They concluded that side difference should be considered while implanting prosthesis on affected side. They obtained radial-head diameter to be 19.04 mm and 18.81 mm in right-sided and left-sided radius respectively.[55]

Rajasree et. al. (2016) conducted a study at department of Anatomy, Narayana Medical College, Nellore. They studied the proximal part of 100 adult dry radii (Right =77 and left=23). Average length was 23.73 cm for right-sided and 23.29 cm for the left-sided and average length of the head was 13.67 mm for right-sided and 13.47 mm for the left-sided radius bone. Diameter of the radial had was 15.41 mm for right-sided and 15.45 mm for the left-sided radius bone while the circumference was 49.10 mm on right side and 48.31 mm on the left. Length of the bicipital tuberosity was 12.20 mm for right-sided and 11.0 mm for the left-sided bone and distance between the radial-head & tuberosity, on average, was 13.67 mm for right-sided and 13.47 mm for the left sided bone. They observed all radius bones to have spherical / discoid shape.[10]

MATERIALS AND METHODS

Source of data :

All 300 dry adult human radius bones (anonymous sex, age & race) were collected from the Department of Anatomy, KAHER's J. N. Medical College, Belagavi, Karnataka, India, for this study.

Study area :

Department of Anatomy, KAHER's J. N. Medical College, Belagavi, Karnataka, India.

Study design :

Observational study.

Study period:

1st January 2020 – 30th June 2021.

Sample size:

The study was performed on 300 dry adult human radius bones (anonymous sex, age & race) collected from the Department of Anatomy, KAHER's J. N. Medical College, Belagavi, Karnataka, India.

Calculation of sample size :

$$\text{Sample size (N)} = \frac{(Z\ \alpha/2)^2\ p\ q}{d^2}$$

Here ,

p = prevalence of the radius bone fractures

q = 100-p

d = relative error (usually not more than 20% of the prevalence)

For the current study , the values taken are as follows :

p = 20% [12]

q = 100-20 = 80

d = 20% of p = 4

Z α/2 = 1.64 (for α = 10%)

Therefore ,

$$N = \frac{(1.64)^2 * 20 * 80}{4^2} = 268.96 \sim \mathbf{300}$$

Selection Criteria:

Inclusion Criteria:

1. Adult normal dried human radius bones irrespective of the sides, sex, age & race.
2. Completely intact bones (intact proximal & distal ends with shaft).
3. Bones without any obvious pathology or deformity.

Exclusion Criteria:

1. Pediatric radius bones.
2. Radius with any deformity / destruction or healed fractures.
3. Broken radius bones.
4. Radius bones with pathology or abnormality.

Materials :

The parameters of all 300 dry adult human radius bones will be measured by using the following equipment & instruments :

1. Osteo-metric board
2. Digital Vernier Caliper
3. Normal ruler
4. Inelastic thread
5. Stamp pad

Photograph 1 : Osteo-metric Board

Photograph 2 : Normal ruler, Digital Vernier Caliper, Inelastic thread , Stamp pad.

Parameters:

The parameters to be measured & analyzed in this study are as follows :

1. Length of the radius bone.
2. Length of the head of radius bone.
3. Diameter of the head of the radius bone.
4. Circumference of the head of the radius bone.
5. Circumference of the neck of the radius bone.
6. Length of the radial tuberosity.
7. Length of ulnar notch .
8. Width of the ulnar notch .
9. Distance between the head of the radius & radial tuberosity .
10. Shape of the head of radius.

Steps for Measurement :

Measurements taken are shown in the following figures (1-4). They were measured as given in Table-1.

Table No.1 : Reference points for measuring each parameter.

S.NO.	PARAMETER	REFERENCE POINTS	FIGURE NO.
1.	Length of the radius bone	R1 = A-E	Fig-1
2.	Length of the radial head	R2 = A-B	Fig-1
3.	Diameter of the radial head	R3 = L-M	Fig-4
4.	Circumference of the head of radius	R4 = Along point F	Fig-2
5.	Circumference of the neck of radius	R5 = Along point G	Fig-2
6.	Length of the radial tuberosity	R6 = C-D	Fig-1
7.	Length of ulnar notch	R7 = H-I	Fig-3
8.	Width of the ulnar notch	R8 = J-K	Fig-3
9.	Distance between the radial head & radial tuberosity of the dry adult human radial bone	R9 = B-C	Fig-1
10.	Shape of the head of radius	Taken as an impression using stamp pad.	Fig-4

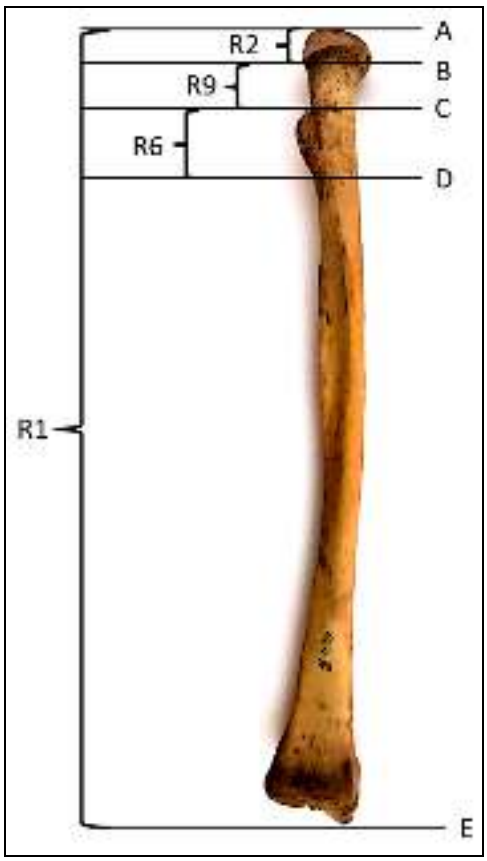


Figure No. 1 : Measurements of the radius bone.

Figure No. 2 : Measurements at proximal part of radius bone.

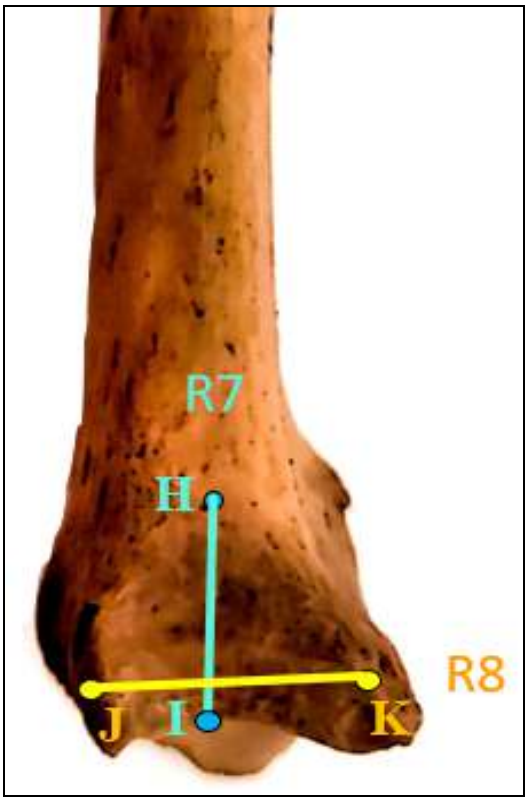


Figure No. 3 : Measurements at distal part of radius bone.

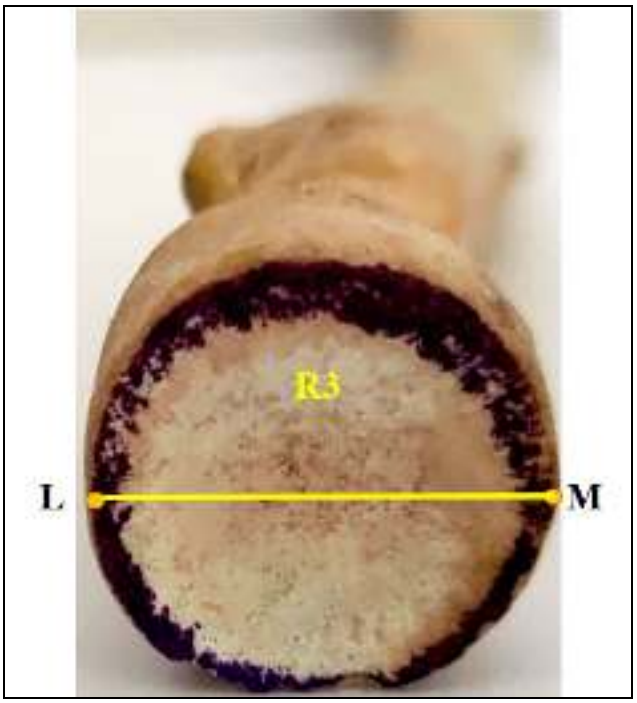


Figure No. 4 : Measurements at the head of the radius bone.

Recording of the parameters:

1. **Length of the radius (R1):**

It was measured using the osteo-metric board, commencing at the proximal-most point of radial-head (A) to distal-most point on styloid process. (E) (Fig-1).It was measured in centimeters.

Photograph No. 3: Measurement of the length of radius bone using an osteo-metric board by the author.

2. Length of the radial head (R2):

It was measured with the help of digital vernier caliper, from upper border of radial-head (A) to the lower border of it (B) (Fig-1). Maximum length was recorded in millimeters.

Photograph No. 4 : Measurement of the length of head of the radius bone using digital vernier caliper (R2).

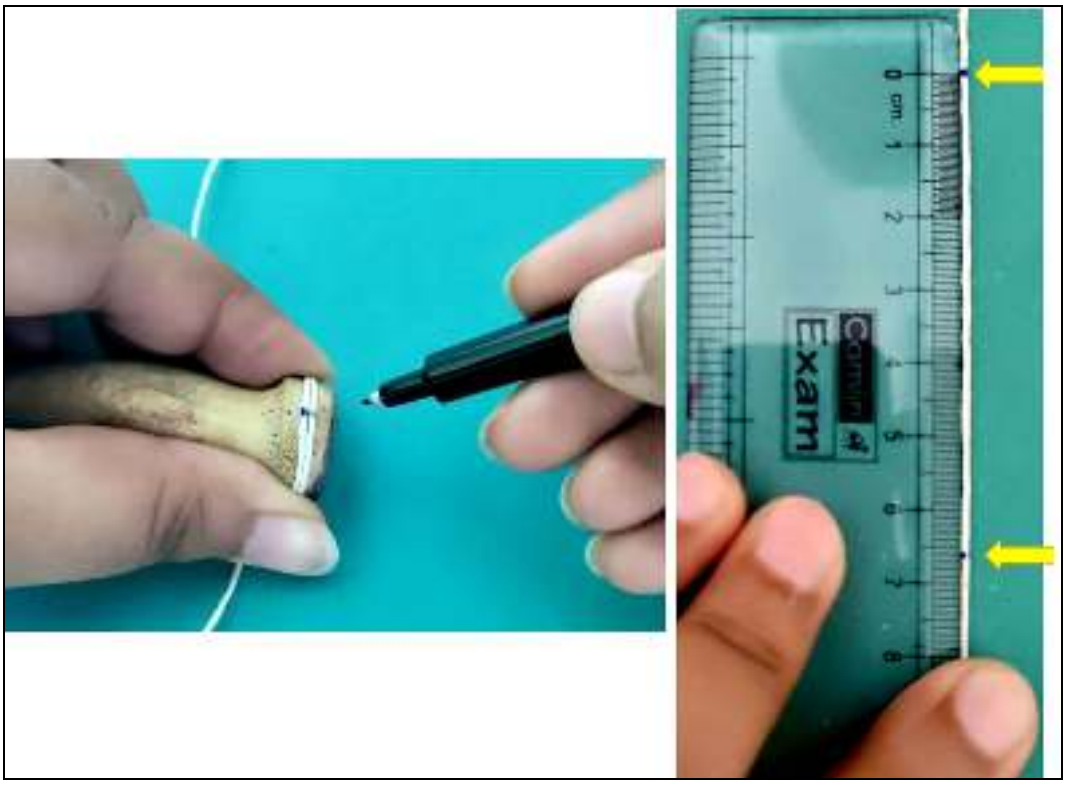
3. Diameter of the radial head (R3) :

It was measured as the maximum reading when the jaws of the digital vernier caliper were kept at the middle of the head of radius bone (Fig-4). It was measured in millimeters.

Photograph No. 5 : Measurement of the diameter of the head of the radius bone using digital vernier caliper.

4. Circumference of the head of radius (R4) :

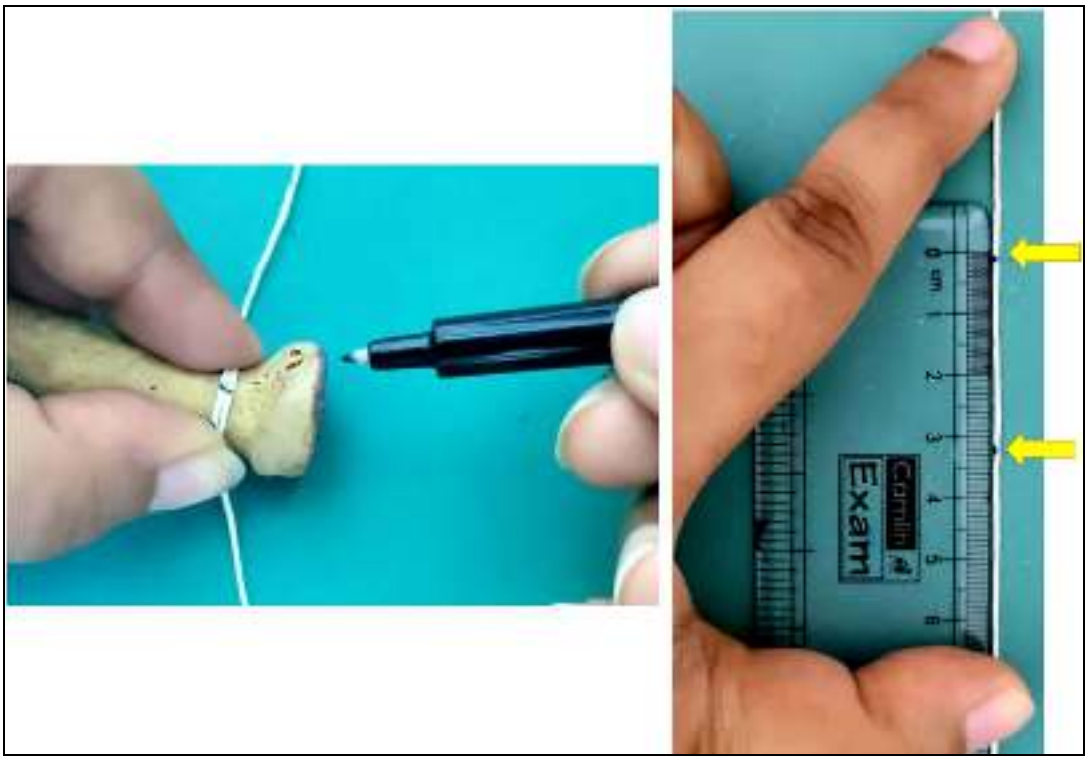
It was measured using an inelastic thread and a normal ruler. The head of the radius was encircled using the inelastic thread (along point F as shown in Fig- 2) and the end was marked. This marked length was then measured by the help of normal ruler. It was measured in centimeters.



Photograph No. 6 : Measurement of the circumference of the head of the radius bone using inelastic thread & normal ruler.

5. Circumference of the neck of radius (R5) :

It was measured using an inelastic thread and a normal ruler. The neck of the radius was encircled using the inelastic thread (along point G as shown in Fig- 2) and the end was marked. This marked length was then measured by the help of normal ruler. It was measured in centimeters.



Photograph No. 7 : Measurement of the circumference of neck of the radius bone using inelastic thread & normal ruler.

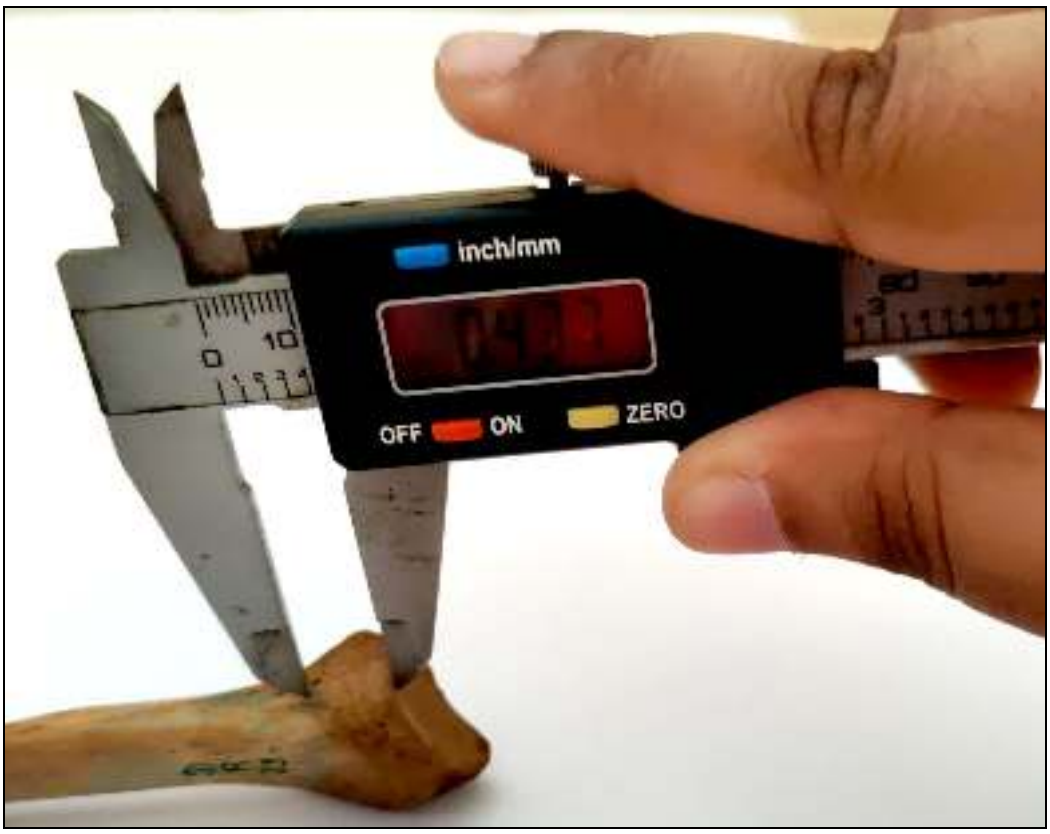
6. Length of the radial tuberosity (R6) :

It was measured with the help of digital vernier caliper, from upper border of radial tuberosity (C) to lower limit of it (D) (Fig-1). Maximum length was noted down in millimeters.

Photograph No. 8 : Measurement of length of the radial tuberosity of the radius bone using digital vernier caliper.

7. Length of ulnar notch (R7) :

This parameter was measured as distance amid the most-proximal point of ulnar-notch along vertical axis (H) & the most distal point of it (I) using digital vernier caliper. The maximum length was noted in millimeters.(Fig-3).



Photograph No. 9 : Measurement of the length of ulnar-notch of radius bone using digital vernier caliper .

8. Width of ulnar notch (R8) :

This parameter was measured as distance between two farthest points of the ulnar-notch along horizontal axis (J & K) (Fig-3) using digital vernier caliper. The maximum length was noted in millimeters.

Photograph No. 10 : Measurement of the width of ulnar-notch of radius bone using digital vernier caliper .

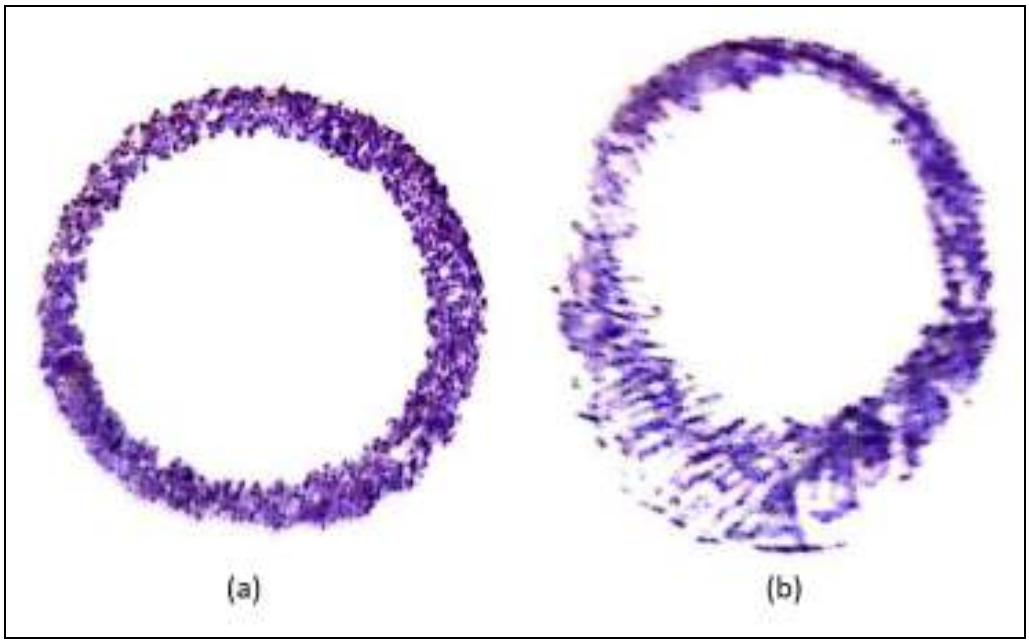
9. Distance between radial-head & radial tuberosity of the dry adult human radial bone (R9) :

The maximum distance between the lower border of the head of the radius (B) and the upper border of the radial tuberosity (C) is measured using digital vernier caliper (Fig-1). It was measured in millimeters.

Photograph No. 11 : Measurement of distance between radial-head & radial-tuberosity of radius bone.

10. Shape of the head of radius :

The shape of head of the radius was determined by taking an impression of it on a plain sheet of paper using stamp pad (Fig-4). It was then categorized as Circular or Oval in shape.



Photograph No. 12 : Impressions of the head of the radius bone to determine its shape as (a) Circular or (b) Oval.

Statistical Analysis

The data was collected, organized & analyzed by using Ms. Excel. Unpaired t-test was applied to compute the range, mean value, standard deviation, 95% confidence interval and P-value for the quantitative-data & Chi-square test was applied for the qualitative-data, for both right & left-sided radius bones. Results were considered significant statistically, whenever $P \leq 0.05$.

RESULTS

OBSERVATIONS

This study was performed on 300 dry adult human radius bones of anonymous sex, age & race, collected from the Department of Anatomy of the institution. Out of these 300 bones, 155 were of left side and 145 of right-side radius bones.

Parameters which were measured & analyzed in the dry adult human radial bones are enumerated below :

1. Length of the radius bone (R1).
2. Length of the radial head (R2).
3. Diameter of the radial head (R3).
4. Circumference of the head of radius (R4).
5. Circumference of the neck of radius (R5).
6. Length of the radial tuberosity (R6).
7. Length of the ulnar notch (R7).
8. Width of the ulnar notch (R8)
9. Distance between the radial head & radial tuberosity of the dry adult human radius bone (R9).
10. Shape of the head of radius (R10).

- These enumerated parameters were evaluated using osteo-metric board, normal ruler (30 cm in length), inelastic thread , digital vernier caliper and stamp pad.

- For an individual parameter, the dimensions were procured for three counts and the mean was documented as the ultimate value. These values were charted in millimeter and centimeter.

- Measurements taken in all 300 dry adult human radius bones are tabulated in ANNEXURE-IV.

- Mean value of all 155 left-sided and 145 right-sided radii were logged as concluding value.

- Statistical analysis was done using Unpaired t-test for the quantitative values (R1-R9) and Chi-square test for the qualitative values (R10).

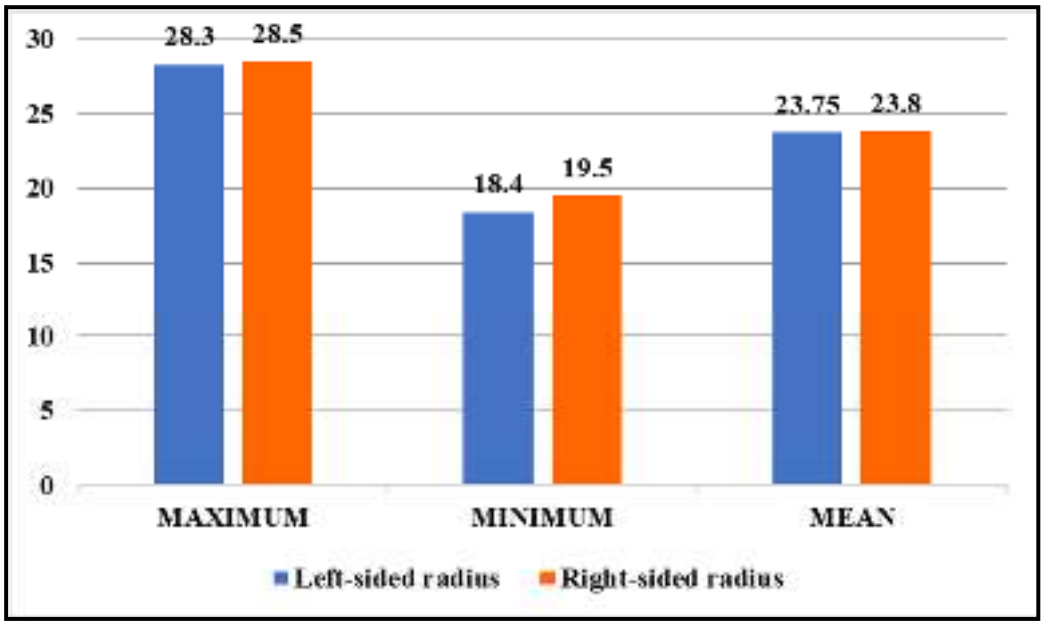
R1 - LENGTH OF THE RADIUS BONE

Following table shows the maximum, minimum, mean length and the standard deviation obtained for both left-sided and right-sided radius bones.

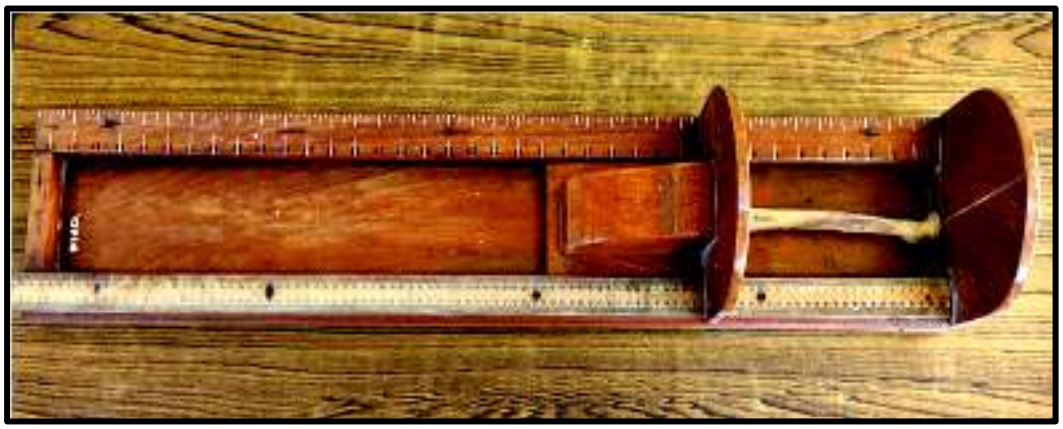
Table No.2 : Assessment of the length of the radius bones (Left-sided and right-sided)

Length of the radius bone (In cm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	28.3	28.5
Minimum	18.4	19.5
Mean	23.75	23.8
Standard deviation	1.91	1.85

Graph-1 : Assessment of the length of the radius bones (Left-sided and right-sided)



Photograph No. 13 : Measurement of length of the left-sided radius bone using osteo-metric board.



Photograph No. 14 : Measurement of length of the right-sided radius bone using osteo-metric board.

- Length of the left-sided radius bone ranged from 18.4 ± 1.91 cm (minimum) to 28.3 ± 1.91 cm (maximum). Mean length was 23.75 ± 1.91 cm.
- Length of the right-sided radius bone ranged from 19.5 ± 1.85 cm (minimum) to 28.5 ± 1.85 cm (maximum). Mean length was 23.8 ± 1.85 cm.
- Mean length of the radius bones irrespective of its side was 23.78 ± 1.88 cm. Range of the length was from 18.4 ± 1.88 cm (minimum) to 28.5 ± 1.88 cm (maximum).

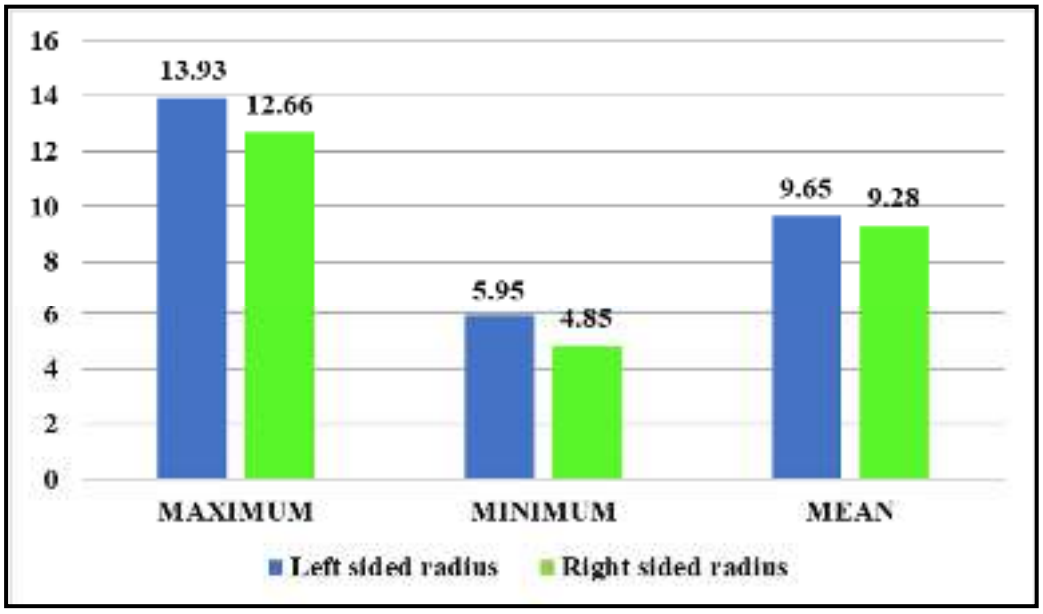
R2 - LENGTH OF THE HEAD OF RADIUS

Following table shows the maximum , minimum, mean length of the head of radius and the standard deviation obtained for both left-sided and right-sided radius bones.

Table No. 3: Assessment of the length of head of the radius bones (Left and right-sided).

Length of the head of radius (In mm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	13.93	12.66
Minimum	5.95	4.85
Mean	9.65	9.28
Standard deviation	1.53	1.44

Graph-2 : Assessment of the length of head of the radius bones (Left and right-sided)



- Length of the head of the left-sided radius bone ranged from 5.95 ± 1.53 mm (minimum) to 13.93 ± 1.53 mm (maximum). Mean length was 9.65 ± 1.53 mm.

- Length of the head of the right-sided radius bone ranged from 4.85 ± 1.44 mm (minimum) to 12.66 ± 1.44 mm (maximum). Mean length was 9.28 ± 1.44 mm.

- Mean length of the head of the radius bones (irrespective of its side) was 9.47 ± 1.49 mm. Range of the length was from 4.85 ± 1.49 mm (minimum) to 13.93 ± 1.49 mm (maximum).

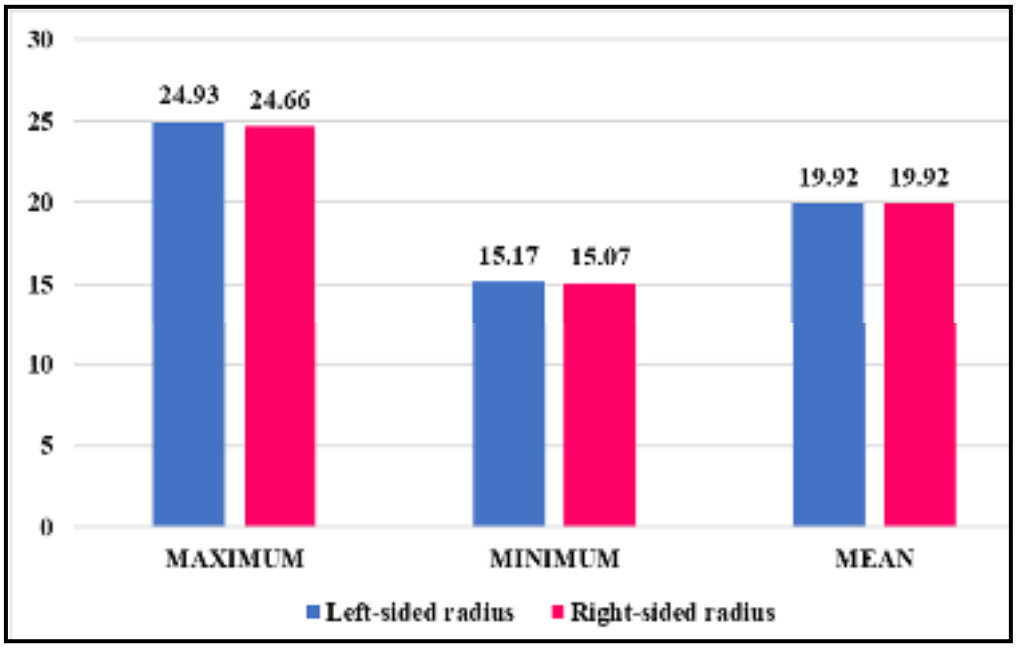
R3 - DIAMETER OF THE HEAD OF RADIUS

Following table shows the maximum, minimum, average diameter of the radial-head and standard deviation obtained for both left-sided and right-sided radius bones.

Table No.4 : Assessment of the diameter of the head of the radius bones (Left and right-sided)

Diameter of the radial-head (In mm.)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	24.93	24.66
Minimum	15.17	15.07
Mean	19.92	19.92
Standard deviation	1.96	2.09

Graph- 3: Assessment of the diameter of the head of the radius bones (Left and right-sided)



- Diameter of the head of the left-sided radius bone ranged from 15.17 ± 1.96 mm (minimum) to 24.93 ± 1.96 mm (maximum). Mean diameter was 19.92 ± 1.96 mm.

- Diameter of the head of the right-sided radius bone ranged from 15.07 ± 2.09 mm (minimum) to 24.66 ± 2.09 mm (maximum). Mean diameter was 19.92 ± 2.09 mm.

- Average diameter of head of the radius bones (irrespective of its side) was 19.92 ± 2.03 mm. Range of the diameter was from 15.07 ± 2.03 mm (minimum) to 24.93 ± 2.03 mm (maximum).

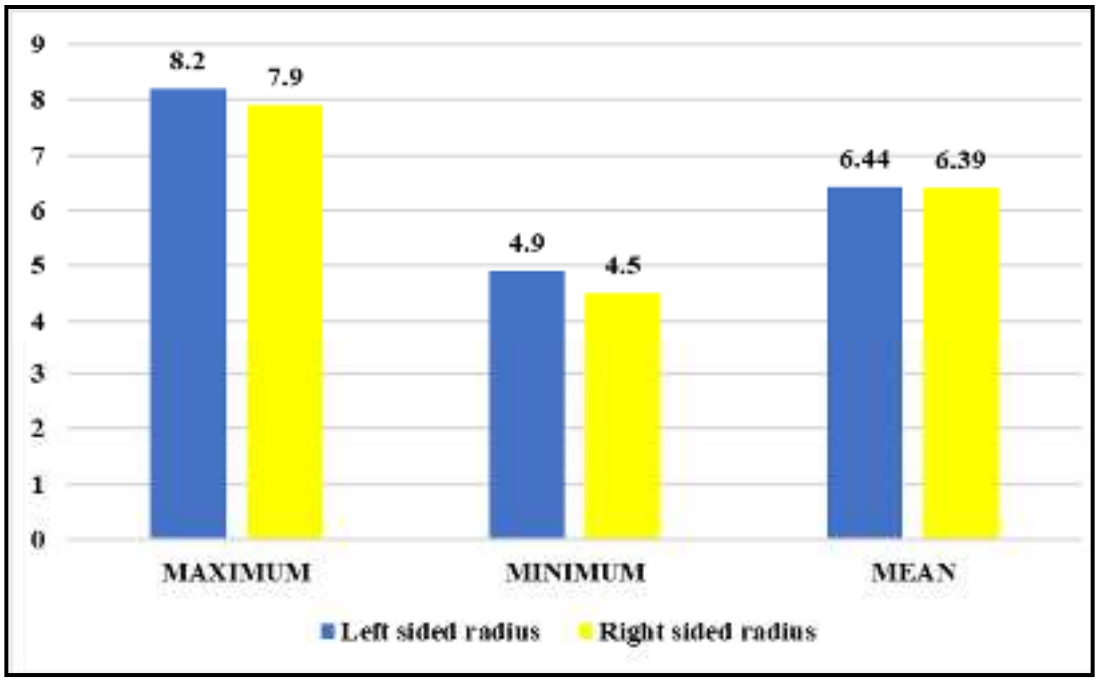
R4 - CIRCUMFERENCE OF THE HEAD OF THE RADIUS

Following table shows the maximum , minimum, mean circumference of the head of radius and the standard deviation obtained for both left-sided and right-sided radius bones.

Table No.5 : Assessment of radial-head circumference (Left & right-sided)

Circumference of the head of radius (In cm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	8.2	7.9
Minimum	4.9	4.5
Mean	6.44	6.39
Standard deviation	0.61	0.64

Graph- 4: Assessment of the radial-head circumference (Left & right-sided)



- Radial-head circumference on the left-sided bone ranged from 4.9 ± 0.61 cm (minimum) to 8.2 ± 0.61 cm (maximum). Mean circumference was 6.44 ± 0.61 cm.

- Circumference of the head of the right-sided radius bone ranged from 4.5 ± 0.64 cm (minimum) to 7.9 ± 0.64 cm (maximum). Mean circumference was 6.39 ± 0.64 cm.

- Mean circumference of the head of the radius bones irrespective of its side was 6.42 ± 0.63 cm. Range of the circumference was from 4.5 ± 0.63 cm (minimum) to 8.2 ± 0.63 cm (maximum).

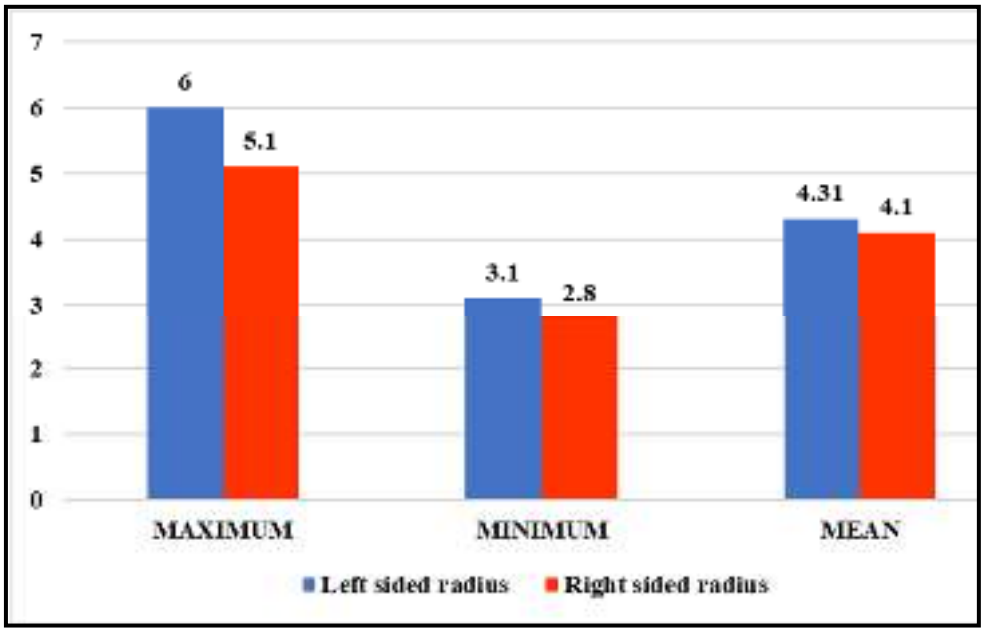
R5 - CIRCUMFERENCE OF THE NECK OF THE RADIUS

Following table shows the maximum , minimum, mean circumference of the neck of radius and the standard deviation obtained for both left-sided and right-sided radius bones.

Table No.6 : Assessment of the circumference of the neck of the radius bones (Left and right-sided)

Circumference of the neck of radius (In cm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	6	5.1
Minimum	3.1	2.8
Mean	4.31	4.1
Standard deviation	0.52	0.51

Graph- 5 : Assessment of the circumference of the neck of the radius bones (Left and right-sided).



- Circumference of the neck of the left-sided radius bone ranged from 3.1 ± 0.52 cm (minimum) to 6 ± 0.52 cm (maximum). Mean circumference was 4.31 ± 0.52 cm.

- Circumference of the neck of the right-sided radius bone ranged from 2.8 ± 0.51 cm (minimum) to 5.1 ± 0.51 cm (maximum). Mean circumference was 4.1 ± 0.51 cm.

- Mean circumference of the neck of the radius bones irrespective of its side was 4.21 ± 0.52 cm. Range of the circumference was from 2.8 ± 0.52 cm (minimum) to 6 ± 0.52 cm (maximum).

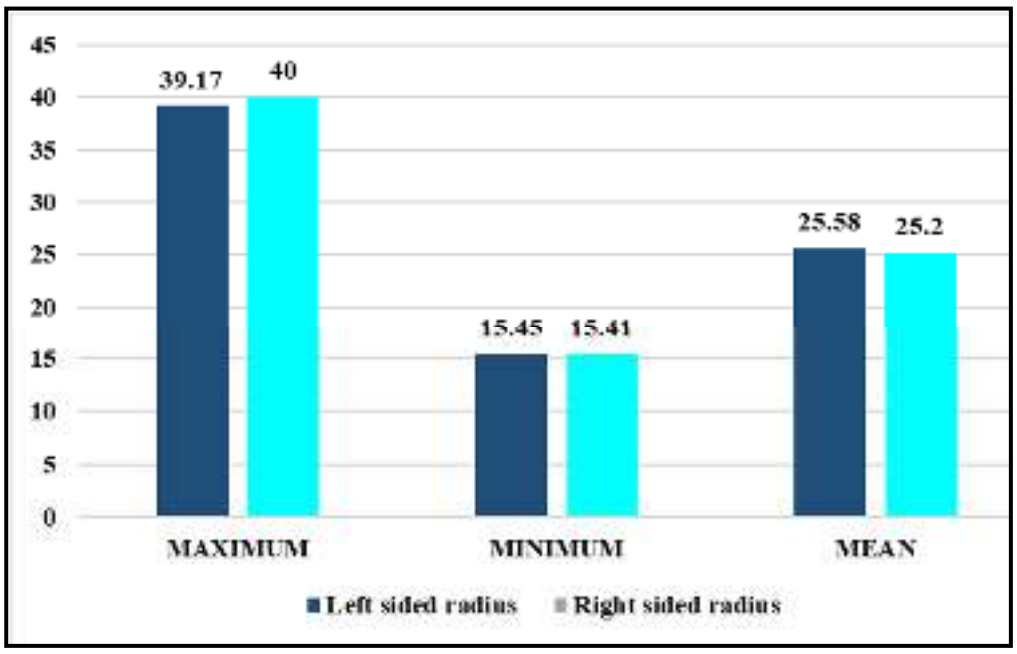
R6 - LENGTH OF THE RADIAL TUBEROSITY

Following table shows the maximum , minimum, mean length of the radial tuberosity and the standard deviation obtained for both left-sided and right-sided radius bones.

Table No.7 : Assessment of the length of the radial-tuberosity. (Left and right-sided)

Length of the radial tuberosity (In mm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	39.17	40
Minimum	15.45	15.41
Mean	25.58	25.2
Standard deviation	4.13	4.94

Graph -6 : Assessment of the length of the radial-tuberosity. (Left and right-sided)



- Length of radial-tuberosity in the left-sided radius bone ranged from 15.45 ± 4.13 mm (minimum) to 39.17 ± 4.13 mm (maximum). Mean length was 25.58 ± 4.13 mm.

- Length of the radial-tuberosity in the right-sided radius bone ranged from 15.41 ± 4.94 mm (minimum) to 40 ± 4.94 mm (maximum). Mean length was 25.2 ± 4.94 mm.

- Mean length of the radial tuberosity of the radius bones irrespective of its side was 25.39 ± 4.54 mm. Range of the length was from 15.41 ± 4.54 mm (minimum) to 40 ± 4.54 mm (maximum).

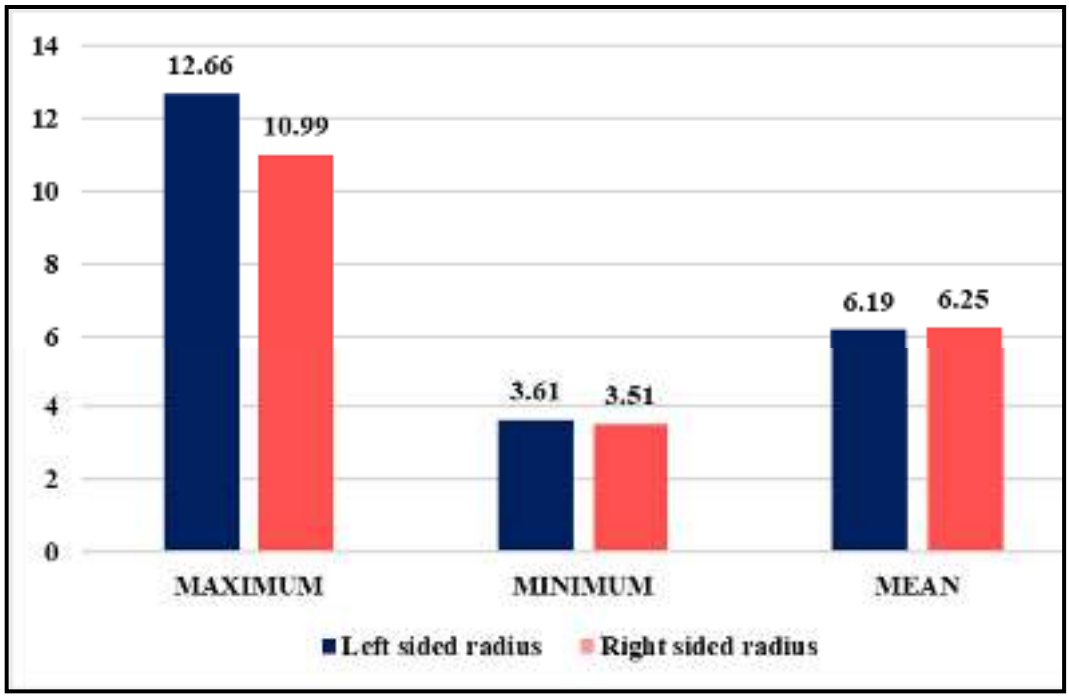
R7 – LENGTH. OF THE ULNAR-NOTCH

Following table shows maximum, minimum, mean length of ulnar-notch and standard deviation obtained for both left-sided and right-sided radius bones.

Table No.8:Assessment of the length of ulnar-notch of radius (Left & right-sided)

Length of the ulnar notch (In mm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	12.66	10.99
Minimum	3.61	3.51
Mean	6.19	6.25
Standard deviation	1.74	1.46

Graph -7 : Assessment of the length of the ulnar-notch of radius bones. (Left & right-sided).



- Length of ulnar-notch of left-sided bone ranged from 3.61 ± 1.74 mm (minimum) to 12.66 ± 1.74 mm (maximum). Mean length was 6.19 ± 1.74 mm.

- Length of the ulnar notch of the head of the right-sided radius bone ranged from 3.51 ± 1.46 mm (minimum) to 10.99 ± 1.46 mm (maximum). Mean length was 6.25 ± 1.46 mm.

- Mean length of the ulnar-notch of the bones irrespective of its side was 6.22 ± 1.6 mm. Range of the length was from 3.51 ± 1.6 mm (minimum) to 12.66 ± 1.6 mm (maximum).

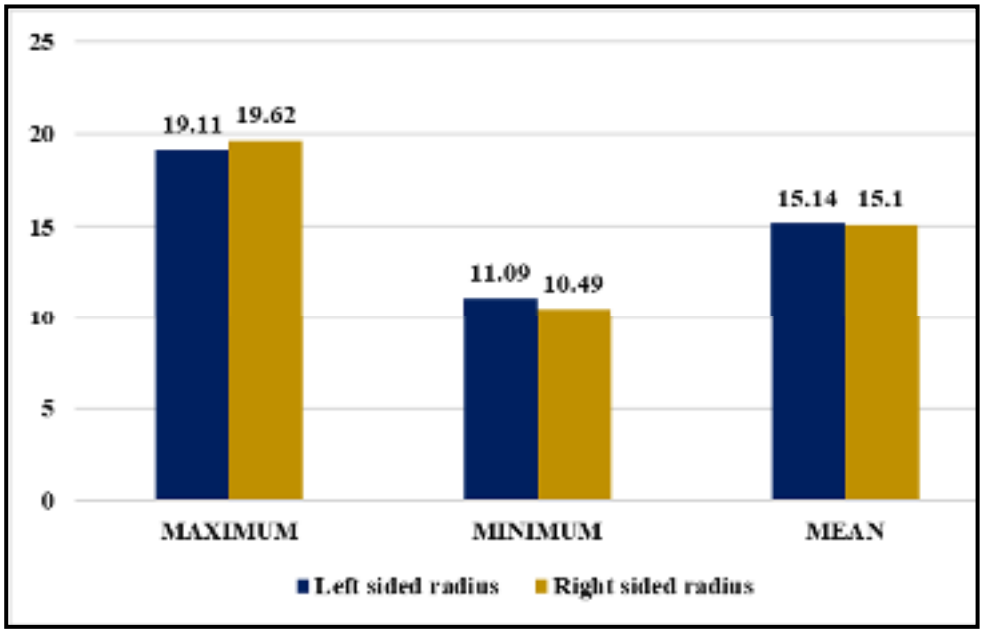
R8 - WIDTH OF THE ULNAR NOTCH

Following table shows the maximum , minimum, mean width of the ulnar notch and the standard deviation obtained for both left-sided and right-sided radius bones.

Table No.9: Assessment of the width of ulnar-notch of radius bones. (Left & right-sided)

Width of the ulnar notch (In mm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	19.11	19.62
Minimum	11.09	10.49
Mean	15.14	15.1
Standard deviation	1.45	1.59

Graph -8 : Assessment of the width of ulnar-notch of radius bones. (Left & right-sided)



- Width of ulnar-notch of left-sided radius ranged from 11.09 ± 1.45 mm (minimum) to 19.11 ± 1.45 mm (maximum). Mean width was 15.14 ± 1.45 mm.

- Width of the ulnar notch of the head of the right-sided radius bone ranged from 10.49 ± 1.59 mm (minimum) to 19.62 ± 1.59 mm (maximum). Mean width was 15.1 ± 1.59 mm.

- Mean width of ulnar-notch of radius irrespective of its side was 15.12 ± 1.52 mm. Range of the width was from 10.49 ± 1.52 mm (minimum) to 19.62 ± 1.52 mm (maximum).

R9 - DISTANCE BETWEEN

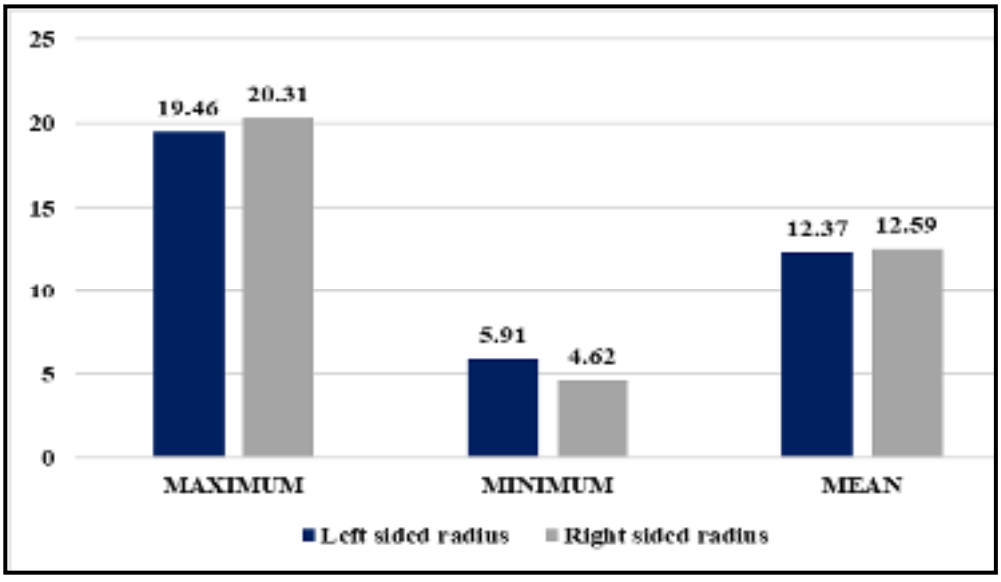
RADIAL-HEAD & RADIAL-TUBEROSITY

Following table shows maximum , minimum, mean distance between radial-head and radial-tuberosity and standard deviation obtained for both left-sided and right-sided radius bones.

Table No.10: Assessment of the distance between radial-head and radial-tuberosity of radius bones. (Left and right-sided)

Distance between radial head and radial tuberosity (In mm)	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Maximum	19.46	20.31
Minimum	5.91	4.62
Mean	12.37	12.59
Standard deviation	2.5	2.67

Graph -9 : Assessment of the distance between radial-head and radial-tuberosity of radius bones. (Left & right-sided)



- Distance between radial-head and radial-tuberosity of the left-sided radius bone ranged from 5.91 ± 2.5 mm (minimum) to 19.46 ± 2.5 mm (maximum). Mean distance was 12.37 ± 2.5 mm.

- Distance between radial-head and radial-tuberosity of the right-sided radius bone ranged from 4.62 ± 2.67 mm (minimum) to 20.31 ± 2.67 mm (maximum). Mean distance was 12.59 ± 2.67 mm.

- Mean distance between radial-head and radial-tuberosity of the radius bones irrespective of its side was 12.48 ± 2.59 mm. Range of the distance was from 4.62 ± 2.59 mm (minimum) to 20.31 ± 2.59 mm (maximum).

R 10 - SHAPE OF THE HEAD OF RADIUS

Following table shows the categorization of shape of the head of radius bones (Left & right-sided) into circular and oval shapes. Their number and percentage are also mentioned.

Table No.11: Categorization of the shape of the head of the radius bones (Left and right-sided)

Shape of the head of the radius	Left-sided radius (n= 155)	Right-sided radius (n= 145)
Circular	102 (66%)	96 (66.21%)
Oval	53 (34%)	49 (33.79%)

Graph -10 : Assessment of the shape of the head of the radius bones (Left and right-sided)

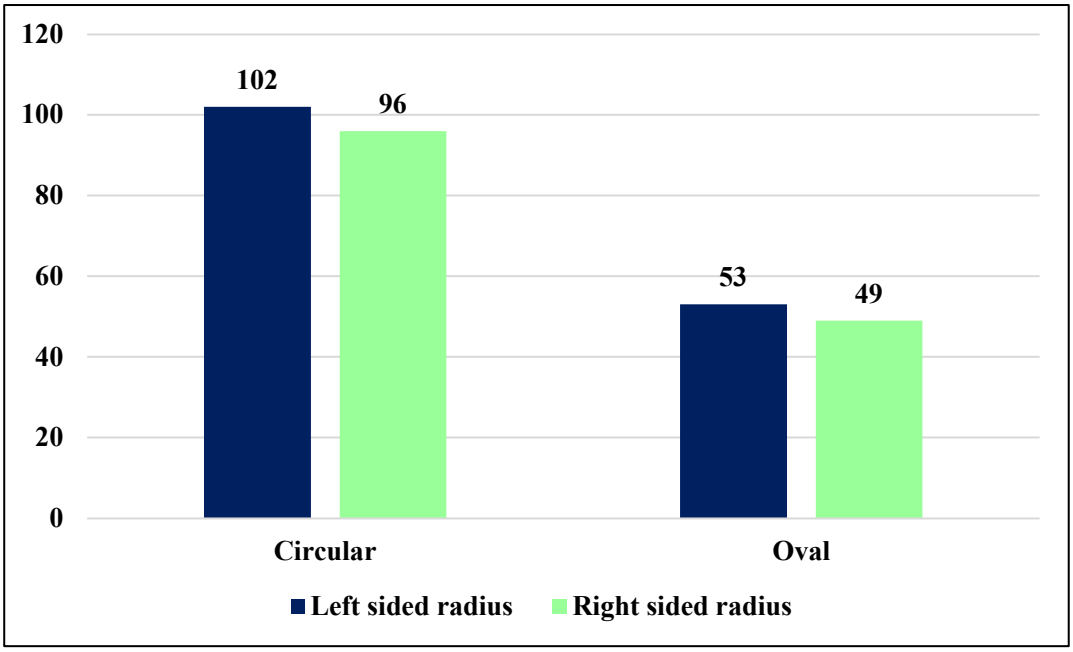


Table No.12 : Showing the mean value of parameters R1-R9 with standard deviation for both right sided and left sided radius bones and overall mean. Also, 95 % Confidence interval and P-value is shown.

PARAMETER	LEFT SIDED RADIUS		RIGHT SIDED RADIUS		OVERALL MEAN VALUE	95 % C.I.	P-value
	Mean	S.D.	Mean	S.D.			
R1 (cm)	23.75	1.91	23.8	1.85	23.78± 1.88	-0.3795 to 0.4765	0.8236 ^{NS}
R2 (mm)	9.65	1.53	9.28	1.44	9.47 ± 1.49	-0.7096 to -0.03306	*0.0315 ^{S}
R3 (mm)	19.92	1.96	19.92	2.09	19.92± 2.03	-0.4585 to 0.4603	0.9969 ^{NS}
R4 (cm)	6.44	0.61	6.39	0.64	6.42 ± 0.63	-0.1840 to 0.09967	0.559 ^{NS}
R5 (cm)	4.31	0.52	4.1	0.51	4.21 ± 0.52	-0.3207 to -0.08590	***0.0007^{S}
R6 (mm)	25.58	4.13	25.2	4.94	25.39± 4.54	-1.412 to 0.6526	0.4699 ^{NS}
R7 (mm)	6.19	1.74	6.25	1.46	6.22 ± 1.6	-0.3048 to 0.4284	0.7403 ^{NS}
R8 (mm)	15.14	1.45	15.1	1.59	15.12± 1.52	-0.3772 to 0.3145	0.8586 ^{NS}
R9 (mm)	12.37	2.5	12.59	2.67	12.48± 2.59	-0.3699 to 0.8051	0.4667 ^{NS}

[*p < 0.05 ; **p < 0.01 ; ***p < 0.001 ; ****p < 0.0001

;S- Statistically significant. , NS – Statistically non-significant]

Only for two parameters - R2 (length of the radial head) and R5 (circumference of the neck) , the P-values obtained are of statistically significant value (0.0315 and 0.0007 respectively). For rest of the parameters, P-values are not statistically significant.

Table No.13 : Association of the shape of the head with sides of the radius bone (left and right).

Shape of the head of the radius	Left-sided radius (n= 155)	Right-sided radius (n= 145)	Chi-square value	P-value
Circular	**102**	**96**	0.0054	0.9417
Oval	**53**	**49**		

DISCUSSION

Radius is the lateral and petite bone of the antebrachium. The forearm entity is formed by two parallel bones hence supination-pronation movements of the forearm are achievable as radius is able to pivot about the ulna during the elbow flexion. Radius bone creates the primary articulation with the hand via wrist distally. Since the ulna does not extend up to wrist, forces received by the hand are conveyed from the radius to ulna via interosseous membrane to be forwarded on to humerus. Proximally, upper aspect of the radial-head connects to the humeral-capitulum providing movements at elbow joint. Medial surface of distal-radius participates in formation of inferior radioulnar joint.

Fracture and dislocation of the radius bone, both isolated or in conjunction with that of ulna bone is quite common. It can occur due to various reasons like FOOSH, sports related injury, road traffic accidents, industrial accidents, pathological fractures due to osteoporosis, malignancies etc.[56] If these fractures are comminuted or the malignancy requires excision of the bone segment, then prosthesis is necessity.[57,58] Many important muscles, tendons, vessels and nerves pass along the radius bone which can be damaged in the injuries are crucial for the normal functioning of the upper limb. Severe pain, loss of strength, decreased range of motion, ,joint instability, malunion, non-union, shortening of the limb, loosening / tightening of the bicipital tendon etc. are the recorded after effects.[59] These can then lead to physical, mental as well as financial burden to the individual. Utmost care should be taken during the treatment and rehabilitation in such cases. It is crucial to restore the normal anatomy of the bone and related structures for hassle-free functioning of an individual and for this thorough knowledge of the relevant anatomical parameters is essential. It will

also help other specialties in better outcomes. A detailed study of various parameters would be of use to orthopedic surgeons, onco-surgeons, physiotherapists, prosthetists, radiologists and also, medicolegal experts in diagnosing, treatment, management and identification of the case.

R1 - LENGTH OF THE RADIUS BONE

Rayna et al (2018)[12] observed the average length of radius bone was 23.70 ± 1.30 cm on right-sided & 23.4 ± 1.27 cm on left-sided radius. Gupta et al (2015)[53] obtained the value of 23.98 ± 1.6 cm on right side, 23.12 ± 2.11 cm on the left and overall mean length of 23.5 ± 1.85 cm. Rajasree G et al (2016)[10] observed this measurement to be 23.73 cm for right-sided and 23.29 cm for the left-sided radius bone. Ethiraj et al (2019)[24] observed the average radial- length as 24.35 ± 1.72 cm for right-side and 23.62 ± 1.69 cm. for the left and overall mean length of the radius as 23.9 ± 1.71 cm.

In the current study, the average length of right-sided radius bone was 23.75 ± 1.91cm and for left-sided radius bone was 23.8 ± 1.85 cm. The overall mean length was found to be 23.78 ± 1.88 cm .The range of the length was determined to be 18.4 ± 1.88 cm to 28.5 ± 1.88 cm.

We can notice minor difference between the length of the two sides in which the right-sided radius is found to be slightly longer than the left-sided in most of the studies which is in contrast to the present study where the left sided radius is found to be slightly longer although the difference is statistically insignificant.

Table No.14 : Comparison of mean length of radius bone in right sided & left sided radius in different studies.

Study	Right-sided radius	Left-sided radius
Present study	23.75 ± 1.91 cm	23.80 ± 1.85 cm
Ethiraj et al (2019)[24]	24.35 ± 1.72 cm	23.62 ± 1.69 cm
Rayna et al (2018)[12]	23.70 ± 1.30 cm	23.40 ± 1.27 cm
Gupta et al (2015)[53]	23.98 ± 1.60 cm	23.12 ± 2.11 cm

R2 - LENGTH OF THE HEAD OF RADIUS

Gupta et al (2015) [53] found mean length of head of radius to be 0.91 ± 0.10 cm for right-sided radius , 0.90 ± 0.13 cm for the left sided radius and overall range as 0.70 - 1.10 cm. Singh A and Singh A (2019)[54] observed the values 7.99 ± 1.39 mm for right-sided, 9.57 ± 1.40 mm for left-sided and 8.65 ± 1.55 mm as the overall mean length. Ethiraj et al (2019)[24] observed the mean length of the head of radius as 0.86 ± 0.10 cm for right-side & 0.95 ± 0.12 cm. for the left-sided radius bone. Rayna et al (2018)[12] noticed it as 0.6 ± 0.07 cm on right-sided & 0.6 ± 0.06 cm on left-sided radius. Shastry et al. (2018)[55] observed the values 9.88 mm and 9.71 mm for right-sided and left-sided radius respectively. Rajasree G et al (2016) [10] observed this measurement to be 13.67 mm for right-sided and 13.47 mm for the left-sided radius bone.

In the current study, the average length of radial-head at right-sided bone was 9.28 ± 1.44 mm and for left-sided radius bone was obtained as 9.65 ± 1.53 mm. The overall mean length of the radial head was found to be 9.47 ± 1.49 mm. The span of length of head of radius was 4.85 ± 1.49 mm to 13.93 ± 1.49 mm.

Results of the present study are nearest to those of Gupta et al (2015)[53] and Shastry et al (2018)[55] but we have found the length to more on the left-sided radius which is in contrast. Also, here one can notice a varied range of values in different studies and within the samples of the same study. On analyzing the result of our study, the difference between the values of right and left-sided radius was found to be statistically significant (P-value = *0.0315 ^{S}).

Table No.15 : Comparison of the mean length of head of the radius bone in right sided and left sided radius in different studies

Study	Right-sided radius	Left-sided radius
Present study	0.93 ± 0.14 cm	0.96 ± 0.15 cm
Ethiraj et al (2019)[24]	0.86 ± 0.10 cm	0.95 ± 0.12 cm
Singh A and Singh A (2019)[54]	0.80 ± 0.14 cm	0.96 ± 0.14 cm
Rayna et al (2018)[12]	0.60 ± 0.07 cm	0.60 ± 0.06 cm
Gupta et al (2015)[53]	0.91 ± 0.10 cm	0.90 ± 0.13 cm

R3 - DIAMETER OF THE HEAD OF RADIUS

Shastry et al. (2018)[55] observed diameter of radial head to be 19.04 mm and 18.81 mm in right-sided and left-sided radius correspondingly. Gupta et al (2015)[53] obtained the value of 1.91 cm as the overall mean value irrespective of the sides. Rajasree G et al (2016)[10] observed this measurement as 15.41 mm for right-sided and 15.45 mm for the left-sided radius bone. Ethiraj et al (2019)[24] observed the mean diameter of the radius as 1.98 ± 0.24 for right-sided and 01.98 ± 00.18 cm for left . Singh A and Singh A (2019)[54] observed the mean values of 19.43 ± 2.39 mm.

In the present study, the mean diameter of head of right-sided radius bone was 19.92 ± 2.09 mm and for left-sided radius bone was obtained as 19.92 ± 1.96 mm. The overall mean diameter of the radial head was found to be 19.92 ± 2.03 mm. The span of diameter of head of radius was 15.07 ± 2.03 mm to 24.93 ± 2.03.

Results of the present study are similar to those of Ethiraj et al (2019)[24] and Singh A and Singh A (2019)[54]. Rajasree G et al (2016)[10] found a significantly less value. On comparing these results statistically , no significant difference was found between the values of both sides but the range of values are varying from study to study.

Table No.16 : Comparison of the mean diameter of head of the radius bone in right sided and left sided radius in different studies

Study	Right-sided radius	Left-sided radius
Present study	19.92 mm	19.92 mm
Ethiraj et al (2019)[24]	19.80 mm	19.80 mm
Shastry et al (2018)[55]	19.04 mm	18.81 mm
Rajasree G et al (2016)[10]	15.41 mm	15.45 mm

R4 - CIRCUMFERENCE OF THE HEAD OF RADIUS

Rayna et al (2018)[12] observed that the mean circumference of the radial-head was 6.3 ± 0.60 cm. on the right-sided and 6.1 ± 00.58 cm on left-sided radius . Rajasree G et al (2016)[10] obtained the mean value of 49.10 mm on right side and 48.31 mm on the left .Van Riet et al (2004)[60] observed the average circumference of the head of radius as 77.5 ± 6.7 mm overall .

In present study, mean circumference of head of right-sided radius bone was 6.39 ± 0.64 cm and for left-sided radius bone was 6.44 ± 0.61 cm. The overall mean circumference of head of the radius bone was found to be 6.42 ± 0.63 cm. The span of the circumference of radial-head was 4.5 ± 0.63 cm to 8.2 ± 0.63 cm.

Results of present study were similar to those of Rayna et al (2018) [12] except for the fact that left-sided value is higher than right-sided in present study. Notably low values were obtained by Rajasree G et al (2016)[10] while high values by Van Riet et al (2004)[60.] On comparing these results statistically , no significant difference was found between the values of both sides but the range of values are varying from study to study.

Table No.17 : Comparison of the mean circumference of head of the radius bone in right sided and left sided radius in different studies

Study	Right-sided radius	Left-sided radius
Present study	6.39 cm	6.44 cm
Rayna et al (2018)[12]	6.30 cm	6.10 cm
Rajasree G et al (2016)[10]	4.91 cm	4.83 cm

R5 - CIRCUMFERENCE OF THE NECK OF THE RADIUS

Rayna et al (2018)[12] observed the mean circumference of neck of radius bone was 4.64 ± 0.53 cm. on right-sided and 04.62 ± 00.51 cm. on left-sided radius.

In present study, the average circumference of neck of the right-sided radius bone was 4.1 ± 0.51 cm and for left-sided radius bone was 4.31 ± 0.52 cm. The overall mean circumference of neck of the radius bone was found to be 4.21 ± 0.52 cm. The range of the circumference of neck of the radius bone was 2.8 ± 0.52 cm to 6 ± 0.52 cm.

On comparing the results of the present study, statistically significant difference was present between the values of right and left sided radius (P-value = ***0.0007^{S}). Also, the results obtained were of slightly lower value than that of Rayna et al (2018).[12]

Table No.18 : Comparison of the mean circumference of neck of the radius bone in right sided and left sided radius in different studies

Study	Present study	Rayna et al (2018)[12]
Right-sided radius	4.10 ± 0.51 cm	4.64 ± 0.53 cm
Left-sided radius	4.31 ± 0.52 cm	4.62 ± 0.51 cm

R6 - LENGTH OF THE RADIAL TUBEROSITY

Gupta et al (2015)[53] found mean length of radial tuberosity of 2.02 ± 0.29 cm for right-sided radius, 1.92 ± 0.35 cm for the left sided. Ethiraj et al (2019)[24] observed the mean length of radial tuberosity as 2.23 ± 0.21 cm for right-sided and 02.33 ± 00.29 cm for left-sided radius bone. Rayna et al (2018) [12] noticed it as 3.36 ± 00.24 cm. on right-sided and 01.23 ± 00.23 cm on left-sided radius. Rajasree G et al (2016)[10] observed this measurement to be 12.20 mm for right-sided and 11.0 mm for the left-sided radius bone.

In the current study, the average length of radial-tuberosity in right-sided radius bone was 25.2 ± 4.94 mm and for left-sided radius bone was obtained as 25.58 ± 4.13 mm. The overall mean length of radial tuberosity of the radius bone was found to be 25.39 ± 4.54 mm. The range of the length of radial tuberosity of the radius bone was 15.41 ± 4.54 mm to 40 ± 4.54 mm.

Results of the present study were found nearest to the Ethiraj et al (2019)[24] study. Noticeable difference was found between the right and left sided values of results in Rayna et al (2018) [12]. Rajasree G et al (2016)[10] observed quite low values. Hence, we can notice a varied range of values in different studies as well as samples of the same study. On comparing the values for right and left sides, difference found

out in present study is statistically insignificant but there is significant difference found out in other studies.

Table No.19 : Comparison of the mean length of radial tuberosity in right sided and left sided radius bone in different studies.

Study	Right-sided radius	Left-sided radius
Present study	2.52 cm	2.56 cm
Ethiraj et al (2019)[24]	2.23 cm	2.33 cm
Rayna et al (2018)[12]	3.36 cm	1.23 cm
Rajasree G et al (2016)[10]	1.22 cm	1.10 cm
Gupta et al (2015)[53]	2.02 cm	1.92 cm

R7 - LENGTH OF THE ULNAR NOTCH

Rayna et al (2018) [12] observed that the mean length of the ulnar notch of the radius bone was 0.30 ± 0.06 cm (anterior) and 0.62 ± 0.07 cm (posterior) on the right-sided and 0.28 ± 0.05 cm (anterior) and 0.60 ± 0.07 cm (posterior) on the left-sided radius.

In the current study, average length of ulnar-notch of right-sided radius bone was 6.25 ± 1.46 mm and for left-sided radius bone was obtained as was 6.19 ± 1.74 mm. The overall mean length of ulnar-notch of radius bone was found to be 6.22 ± 1.6 mm. The range of length of ulnar-notch of radius bone was 3.51 ± 1.6 mm. to 12.66 ± 1.6 mm.

On comparing the results, ulnar notch was quite longer in present study than in Rayna et al (2018) [12]. Difference between the values of right and left sided radius was found to be statistically insignificant in both of the studies . Also ,the results obtained were of quite higher value than that of Rayna et al (2018)[12].

R8 - WIDTH OF THE ULNAR NOTCH

Rayna et al (2018)[12] observed that the mean width of the ulnar-notch was 1.41 ± 0.08 cm. on right-sided and 01.40 ± 00.07 cm on left-sided radius.

In present study, the average width of ulnar-notch of right-sided radius bone was 15.1 ± 1.59 mm and for left-sided radius bone was obtained as 15.14 ± 1.45 mm. The overall mean width of ulnar-notch of radius bone was found to be 15.12 ± 1.52 mm. The range of width of ulnar-notch of radius bone was 10.49 ± 1.52 mm to 19.62 ± 1.52 mm.

On comparing the results, ulnar notch was quite wider in present study than in Rayna et al (2018)[12] .Difference between the values of right and left sided radius was found to be statistically insignificant in both of the studies. Also ,the results obtained were of quite higher value than that of Rayna et al (2018)[12].

Table No.20 : Comparison of the mean width of ulnar notch of right sided and left sided radius bone in different studies.

Study	Present study	Rayna et al (2018)[12]
Right-sided radius	1.51 ± 0.16 cm	1.41 ± 0.08 cm
Left-sided radius	1.51 ± 0.15 cm	1.40 ± 0.07 cm

R9 - DISTANCE BETWEEN

RADIAL- HEAD & RADIAL-TUBEROSITY

Gupta et al (2015)[53] found mean distance between radial-head and radial-tuberosity (Radial-neck) to be 1.18 ± 0.25 cm for right-sided radius, 1.20 ± 0.31 cm for the left sided radius and range of 0.70 - 1.90 cm for right-sided and 00.70 ± 2.10 cm. for left. Ethiraj et al (2019)[24] observed the values as 1.32 ± 00.22 cm for right-sided and 01.26 ± 0.27 cm for left-sided radius bone. Rayna et al (2018)[12] noticed it as 0.75 ± 0.11 cm. on right-sided and 00.73 ± 00.9 cm. on left-sided radius. Rajasree G et al (2016)[10] observed this measurement to be 13.67 mm for right-sided and 13.47 mm for the left-sided radius bone.

In the present study, the mean distance between radial-head & radial-tuberosity (Radial-neck) in right-sided radius bone was 12.59 ± 2.67 mm and for left-sided radius bone was 12.37 ± 2.5 mm. The overall mean distance was found to be 12.48 ± 2.59 mm. The range of distance between the radial-head and radial-tuberosity (Radial neck) was 4.62 ± 2.59 mm to 20.31 ± 2.59 mm.

Here, we can notice that Rajasree et al (2016)[10] obtained a higher value while Rayna et al (2018)[12] the lowest. Results of the present study were most near to Ethiraj et al (2019)[24] study. Difference between the values of this parameter in right and left sided radius was found to be statistically insignificant.

Table No.21: Comparison of the mean distance between the radial-head and radial-tuberosity of right sided and left sided radius bone in different studies

Study	Right-sided radius	Left-sided radius
Present study	1.26 cm	1.24 cm
Ethiraj et al (2019)[24]	1.32 cm	1.26 cm
Rayna et al (2018)[12]	0.75 cm	0.73 cm
Rajasree G et al (2016)[10]	1.37 cm	1.35 cm
Gupta et al (2015)[53]	1.18 cm	1.20 cm

R 10 - SHAPE OF HEAD OF RADIUS

Gupta et al (2015)[53] found shape of radial-head to be circular in 64 %, Oval in 26% and irregular in 10 % radius. Ethiraj et al (2019)[24] observed the circular shape in 65% and 35% oval. Rayna et al (2018)[12] noticed 77.5 % circular, 18.75 % Elliptical and rest of irregular shape. Rajasree G et al (2016)[10] observed all radius bones to have spherical / discoid shape.

In present study, shape of the radial head was found to be circular in 66.21 % , oval in 33.79 % of right side while 66 % circular and 34 % oval in left sided radius bone. None of the bones had irregular or elliptical or any other shape.

Results of the present study is similar to that of Ethiraj et al (2019)[24.] Insignificant difference is found in between the results for shape of the head in right sided and left sided radius bone.

Table No.22: Comparison of the shape of the head of radius of right sided and left sided radius bone in different studies

Study	Circular	Oval	Irregular	Others
Present study	66.1 %	33.90 %	-	-
Ethiraj et al (2019)[24]	65 %	35 %	-	-
Rayna et al (2018)[12]	77.5 %	-	3.75 %	18.75 % Elliptical
Rajasree G et al (2016)[10]	100 %	-	-	-
Gupta et al (2015)[53]	64 %	26 %	10 %	-

CONCLUSION

After exploring 300 dry adult human radius bones (155 left-sided and 145 right-sided) of anonymous sex, age & race, collected from the Department of Anatomy of the institution, following inference were drawn :

- ✓ Mean length of the radius bones irrespective of its side was 23.78 ± 1.88 cm. Range of the length was from 18.4 ± 1.88 cm (minimum) to 28.5 ± 1.88 cm (maximum).
- ✓ Mean length of the head of the radius bones (irrespective of its side) was 9.47 ± 1.49 mm. Range of the length was from 4.85 ± 1.49 mm (minimum) to13.93 ± 1.49 mm (maximum).
- ✓ Mean diameter of the head of the radius bones (irrespective of its side) was 19.92 ± 2.03 mm. Range of the diameter was from 15.07 ± 2.03 mm (minimum) to 24.93 ± 2.03 mm .
- ✓ Mean circumference of the head of the radius bones irrespective of its side was 6.42 ± 0.63 cm. Range of the circumference was from 4.5 ± 0.63 cm (minimum) to 8.2 ± 0.63 cm (maximum).
- ✓ Mean circumference of the neck of the radius bones irrespective of its side was 4.21 ± 0.52 cm. Range of the circumference was from 2.8 ± 0.52 cm (minimum) to 6 ± 0.52 cm (maximum).
- ✓ Mean length of the radial tuberosity of the radius bones irrespective of its side was 25.39 ± 4.54 mm. Range of the length was from 15.41 ± 4.54 mm (minimum) to 40 ± 4.54 mm (maximum).

- ✓ Mean length of ulnar notch of radius bones irrespective of its side was 6.22 ± 1.6 mm. Range of the length was from 3.51 ± 1.6 mm (minimum) to 12.66 ± 1.6 mm (maximum).
- ✓ Mean width of ulnar notch of radius bones irrespective of its side was 15.12 ± 1.52 mm. Range of the width was from 10.49 ± 1.52 mm (minimum) to 19.62 ± 1.52 mm (maximum).
- ✓ Mean distance between radial head and radial of the radius bones irrespective of its side was 12.48 ± 2.59 mm. Range of the distance was from 4.62 ± 2.59 mm (minimum) to 20.31 ± 2.59 mm (maximum).
- ✓ Shape of head of radius (overall) was found to be circular in 66.1 % and oval in 33.9 % of the radius bones. None of the bones had irregular , elliptical or any other shape.
- ✓ Only for two parameters - R2 (length of the radial head) and R5 (circumference of the neck), the P-values obtained are of statistically significant value (*0.0315 and ***0.0007 respectively). For rest of the parameters, P-values are statistically insignificant.
- ✓ Wide range of values of the various parameters are found on comparison with other studies of different regions and populations. Also, for certain parameters, statistically significant difference was found in between the values of the right sided and left sided radius bones.
- ✓ Thus, care must be taken while treating or prosthesis making so that minimum unwanted outcomes are faced and maximum functionality is achieved by the patient.

SUMMARY

The present study was undertaken with an aim to appraise the morphometric measurements of the dry adult human radius bone in Belagavi region of Karnataka. The objectives were to evaluate the dimensions of the proximal end, distal end & the shaft of the dry adult human radius bone and to collate these dimensions between the right-sided & left-sided radius bones.

300 dry adult human radius bones (155 left-sided and 145 right-sided) of anonymous sex, age & race, collected from the Department of Anatomy, KAHER's J. N. Medical College, Belagavi, Karnataka, India, were systematically investigated and the data was then analyzed to obtain the results.

All adult normal dried human radius bones, irrespective of the sides, sex, age & race, without any obvious pathology or deformity and completely intact bones were counted in the study sample. Pediatric bones, bones with any deformity / destruction or healed fractures, broken radius and with any pathology or abnormality were omitted.

The parameters which were assessed & analyzed were length of radius bone (R1), length of radial head (R2), diameter of radial head (R3), circumference of head of radius (R4), circumference of neck of radius (R5), length of radial tuberosity (R6), length of the ulnar notch (R7), width of the ulnar notch (R8), distance between radial head & radial tuberosity (R9) and shape of head of radius (R10).

The measurements were taken cautiously using osteo-metric board, digital vernier caliper, normal ruler, inelastic thread and stamp pad. The data was then

compiled and structured using Ms. Excel. Statistical analysis was executed by applying Unpaired t-test to compute the range, mean value, standard deviation, 95% confidence interval and P-value for the quantitative data and Chi-square test for the qualitative data, for both right & left sided radius bones. Results were considered statistically significant whenever $P \leq 0.05$.

Mean values of the individual parameters was calculated (for each side as well as overall mean). Only for two parameters - R2 (length of the radial head) and R5 (circumference of the neck), the P-values obtained were statistically significant (0.0315 and 0.0007 respectively). For rest of the parameters, P-values were statistically insignificant.

Wide-ranging values of the various parameters were obtained on appraisal with other studies of different regions and populations. Also, for certain parameters, statistically significant difference was realized in between the values of right sided and left sided radius bones.

Hence, knowledge of the range of values and the variations of all the parameters in right and left sided radius bone of the same individual as well as in different populations will facilitate better outcomes in the treatment of patients with fracture of radius, to implant appropriate prosthesis and to construct customized prosthesis in case of possible high variance in dimensions. All these values can vary according to the race, geographical area, stature etc. Clinically, this research plays an imperative role for anatomists, clinicians, orthopedic surgeons, onco-surgeons, physiotherapists, radiologists, forensic experts, archeologists, ,biomedical engineers and prosthetists as the radius bone is inadequately explored if compared to the other pivotal bones of the human body.

One must keep in mind that radius bone is crucial for the supination and pronation movements of the forearm which is present exclusively in the humans. More research is required for this bone as the data available currently is unsatisfactory and it can be studied more for the benefit of the society, in general.

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ANNEXURES

ANNEXURE-I : ETHICAL CLEARANCE LETTER

K.L.E. ACADEMY OF HIGHER EDUCATION AND RESEARCH
(Deemed - to-be-University)
Accredited 'A' Grade by NAAC (2nd Cycle) Placed in Category 'A' by MHRD (GoI)

JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)

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Ref: MDC/DOME/ 198 **Date: 24/12/2019**

To,

REG. NO: BB0119001

J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"MORPHOMETRIC ANALYSIS OF THE DRY ADULT HUMAN RADIUS BONE: AN OBSERVATIONAL STUDY",** is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Nalini Dalal)
Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Roopa M Bellad)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

ANNEXURE-II : PHOTOGRAPHS

Photograph No. 15 : 155 left-sided dry adult human radii.

Photograph No. 16 : 145 right-sided dry adult human radii.

ANNEXURE III: PROFORMA OF THE STUDY

1. Specimen Number :
2. Side of the radii : Left / Right
3. Parameters : measured in cm / mm / qualitative value (circular/oval/others)

LEFT SIDED RADIUS										
S. No.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**

RIGHT SIDED RADIUS										
S. No.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**

R1 : Length of the radius bone

R2 : Length of the radial head

R3 : Diameter of the radial head

R4 : Circumference of the head of radius

R5 : Circumference of the neck of radius

R6 : Length of the radial tuberosity

R7 : Length of the ulnar notch

R8 : Width of the ulnar notch

R9 : Distance between the radial head & radial tuberosity of the dry adult human radius bone

R10: Shape of the head of radius

ANNEXURE VI:

KEY TO MASTERCHARTS

R1 : Length of the radius bone (in cm)

R2 : Length of the radial head (in mm)

R3 : Diameter of the radial head (in mm)

R4 : Circumference of the head of radius (in cm)

R5 : Circumference of the neck of radius (in cm)

R6 : Length of the radial tuberosity (in mm)

R7 : Length of the ulnar notch (in mm)

R8 : Width of the ulnar notch (in mm)

R9 : Distance between the radial head & radial tuberosity of the dry adult human radius bone (in mm)

R10 : Shape of the head of radius (Circular / Oval / Others)

MASTERCHARTS

LEFT SIDED RADIUS BONES										
S. NO.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
1	20.8	10.23	17.8	6	3.8	22.65	7.98	14.06	10.04	Circular
2	24	7.88	17.78	5.9	4.6	20.16	8.14	13.54	12.95	Oval
3	22.7	10.67	17.72	6	4.1	21.84	6.72	13.77	9.4	Circular
4	24	8.45	18.26	5.9	4.4	21.38	9.97	13.86	11.15	Circular
5	22.5	8.86	19.79	8.2	6	20.03	10.03	15.01	13.19	Oval
6	23.8	9.75	18.27	7.5	4.8	21.61	12.66	16.94	14.42	Circular
7	23.9	8.74	18.76	5.5	4.5	22.6	8.43	15.6	11.58	Circular
8	20.1	8.53	16.36	5.8	4.3	23.18	6.37	15.55	5.94	Circular
9	24.8	11.45	24.3	7.8	5	27.17	12.26	17.33	12.85	Circular
10	24.8	9.32	20.39	6.5	4.5	21.12	7.43	15.33	12.22	Circular
11	22.3	8	16.86	5.5	3.4	15.45	6.1	14.72	10.06	Circular
12	25.3	8.51	21.74	6.9	4.6	32.54	4.84	15	15.89	Circular
13	27.5	12.98	20.32	6.5	4.5	25.28	6.13	14.01	12.62	Circular
14	24.9	12.38	22.08	6.9	4.8	22.77	5.84	16.88	9.07	Circular
15	22.8	10.09	18.94	6.1	4.5	24.07	7.54	12.48	12.33	Circular
16	24.2	7.9	20.54	6.5	5.2	25.02	4.87	14.1	12.24	Circular
17	22.8	8.27	20.14	6.9	4.4	25.42	5.67	15.47	14.49	Circular
18	22.7	8.12	18.08	5.9	4.3	23.02	6.28	14.7	16.23	Circular
19	23.1	9.29	18	6.5	4	23.19	4.99	15.52	12.98	Circular
20	23.7	9.56	19.07	6.4	3.6	22.66	6.78	13.59	12.61	Circular
21	25.2	10.09	20.46	6.9	4.7	31.5	5.79	15.79	14.07	Circular
22	25.7	9.67	23.12	7.9	5	27.7	5.36	16.26	13.28	Circular
23	19.5	5.95	17.32	5.6	3.5	19.58	3.61	12.07	14.16	Circular
24	23.6	6.94	20.82	6.9	4.9	27.61	5.98	15.45	6.85	Circular
25	24.6	9.47	19.24	6.5	4.4	29.27	5.77	13.42	13.14	Circular
26	25.9	10.08	20.74	6.5	4.4	25.77	5.26	14.75	11.96	Oval
27	24.3	7.22	23.4	7.6	4.9	28.72	5.49	15.95	15.95	Circular
28	24	7.94	19.23	6.1	4.4	25.75	5.37	14.66	14.89	Circular
29	24.3	7.65	18.8	6	4.8	25.15	4.31	14.98	13.4	Circular
30	25	10.1	21.63	6.6	5.1	26.85	6.09	16.13	12.34	Circular
31	22.9	8.54	22.67	7.3	4.9	29.98	6.55	17.31	15.02	Circular
32	26.1	7.44	21.45	6.9	4.9	29.88	5.85	14.46	14.4	Oval
33	23.6	7.9	21	6.3	4.1	28.01	4.86	13.39	13.51	Oval
34	23.6	8.75	18.75	6	3.7	24.22	4.52	14.64	11.06	Circular
35	23.5	7.78	21.41	6.9	4.7	25.32	4.33	13.7	19.46	Oval
36	25.6	8.15	20.35	6.6	4.6	23.22	4.2	15.07	17.05	Circular
37	23.9	7.8	17.95	6.1	3.8	39.17	4.27	13.52	13.26	Circular
38	26.5	10.98	23.12	7	4.4	30.3	4.44	16.66	18.74	Circular
39	22	10.06	20.68	6.3	3.9	30.21	6.06	12.95	18.08	Oval
40	22.4	8.97	20.78	6.7	5.2	36.52	5.38	17.76	15.58	Circular
41	23.5	9.3	21.28	6.7	4.3	19.95	6.7	14.96	10.06	Circular
42	23.6	8.56	18.09	6	3.7	24.65	4.26	14.08	12.25	Circular
43	24.1	9.51	20.77	6.9	4.9	20.5	6.47	16.49	10.67	Circular
44	24.1	10.11	20.98	6.8	4.4	26.72	6.13	16.76	10.27	Circular
45	22.7	8.03	18.16	6.6	3.5	25.68	4.81	14.58	8.15	Oval
46	25.1	9.55	20.54	6.6	4.8	22.43	4.35	15.88	14.79	Circular
47	24.6	9.96	19.93	6.5	4.3	24.04	5.49	15.65	9.38	Circular
48	21.8	8.61	17.85	5.4	3.5	27.2	6.26	14.02	12.85	Circular
49	25.5	8.82	22.14	6.9	4.4	25.75	5.84	17.71	11.92	Circular
50	24.6	10.18	20.69	7	4.6	23.57	7.8	18.31	14.64	Circular

51	22.7	8.35	19.15	6.2	4	26.37	5.04	17.53	11.63	Circular
52	22.8	7.2	17.02	5.4	3.6	23.91	3.83	14.74	10.28	Oval
53	24.9	10.9	22.64	7.3	5.3	34.02	5.47	14.7	12.2	Oval
54	22.4	8	17.96	5.9	4	23.79	5.06	14.15	11.96	Circular
55	25	9.34	20.38	6.3	4.4	28.92	5.65	15.45	12.44	Oval
56	24.1	9.37	20.22	6.4	4	21.6	6.09	16.53	13.32	Oval
57	22.6	12.54	22.24	5.5	3.1	25.04	10.33	19.11	16.02	Circular
58	22.1	8.61	17.61	5.6	3.4	22.98	5.24	13.62	12.93	Oval
59	20.9	9.27	18.1	5.7	3.9	28.49	4.06	15.62	10.19	Oval
60	23.7	9.82	21.23	6.4	4.1	27.96	4.57	17.6	13.36	Oval
61	22.8	11.34	20.27	6.4	4	25.07	5.28	15.14	11.69	Oval
62	22.3	9.42	19.68	6	4	21.68	6.68	16.59	12.25	Oval
63	22.8	10.67	21.51	6.8	4.5	28.27	5.63	14.2	13.15	Oval
64	20.4	6.88	15.71	4.9	3.5	26.33	4.4	12.96	13.11	Circular
65	22.5	7.6	19.53	6.1	4.1	25.18	6.13	15.41	13.63	Oval
66	26.7	7.69	20.3	6.4	4	28.13	4.91	15.55	15.71	Circular
67	24.7	9.41	18.89	5.9	4	20.82	4.63	15.11	11.08	Oval
68	26.6	11.22	21.31	6.8	4.4	21.1	7.2	15.09	13.1	Oval
69	20.9	8.02	16.45	5.3	3.6	16.42	7.72	14.72	12.46	Oval
70	20.8	7.86	18.02	5.6	3.5	27.63	5.1	17.09	9.98	Circular
71	27.8	11.48	24.82	7.6	5.4	34.41	9.33	17.1	14.01	Oval
72	22.4	8.79	18.42	6	4.6	21.62	7.44	16.03	11.12	Circular
73	20.8	7.86	18.44	5.9	3.5	17.48	8.83	14.53	9.42	Oval
74	19.9	7.36	15.48	5.1	3.2	20.22	4.63	11.79	10.82	Circular
75	20.1	10.08	17.18	5.9	3.5	22.04	7.38	15.27	10.1	Circular
76	18.4	8.42	19.72	6	4.1	20.27	10.01	13.06	7.51	Oval
77	23.3	8.55	16.44	5.2	3.7	22.47	9.04	14.08	13.3	Circular
78	24.3	11.74	23.11	7.2	4.9	27.11	7.77	16.03	10.92	Oval
79	23.5	8.91	20.62	6.6	5.1	32.58	4.9	14.43	9.97	Oval
80	24.4	9.54	21.55	6.6	4.4	24.91	7.78	14.41	9.86	Oval
81	21.8	9.51	19.32	5.9	3.6	21.32	6.89	15.68	10.06	Oval
82	25.8	9.29	21.5	6.5	4.7	20.52	5.38	15.45	12.22	Circular
83	23.8	9.93	19.22	6.1	4.6	26.24	5.79	14.26	11.86	Oval
84	22.2	9.42	17.81	5.9	4.2	25.29	4.11	11.09	12.25	Circular
85	23.7	8.97	22	7.6	4.4	21.23	5.81	16.6	12.46	Circular
86	23.9	8.7	17.2	6	4.1	23.25	8.38	13.03	11.67	Circular
87	24.3	9.48	19.33	6.2	4.3	27.5	4.42	14.08	14.1	Circular
88	22.9	7.95	19.36	6.3	4.2	22.91	4.92	12.76	11	Oval
89	24.2	9.98	21.92	6.9	4.1	21.34	7.05	16.63	15.84	Circular
90	22.3	9.69	22.14	7	5	35.47	10.38	18.1	9.49	Circular
91	24.1	11.11	19.26	6.1	4.6	26.4	6.14	16.99	12.1	Circular
92	25.8	8.87	20.18	6.6	4.4	23.37	4.74	16.03	12.48	Circular
93	23.6	9.07	18.29	6.4	4.5	26.81	6.58	15.3	10.46	Circular
94	22.7	9.55	19.19	6.3	4.1	22.49	4.24	15.87	9.75	Circular
95	25.3	13.01	20.69	7	4.2	31.08	5.07	17.7	13.24	Oval
96	25	12.01	20.92	6.8	5.1	24.66	5.57	15.36	13.15	Circular
97	23.4	9.17	19.03	6.1	4	34.1	6.59	16.13	8.88	Circular
98	24.2	10.66	23.36	7.3	4.6	32.78	5.68	15.08	16.47	Oval
99	27.7	11.89	22.74	7.5	5	27.92	4.95	16.84	13.82	Oval
100	25.9	10.52	20.6	6.4	4.5	27.56	7.17	15.3	13.96	Circular
101	24.5	10.42	19.68	6	4.6	23.52	4.79	15.28	11.88	Oval
102	26.7	11.55	20.29	6.5	4.3	27.02	6.12	17.25	10.79	Circular
103	23.6	10.97	21.19	7.2	4.5	24.59	3.71	15.99	11.62	Circular
104	20.7	11.1	16.2	6.2	4	22.13	5.43	13.99	8.81	Circular
105	25	10.05	20.54	6.6	3.9	28.43	4.97	12.59	13.65	Circular
106	25.4	10.22	20.89	6.9	4.3	24.02	6.16	15.21	17.2	Circular
107	23.4	12.16	17.63	6.4	3.9	25.56	8.7	17.1	8.38	Circular

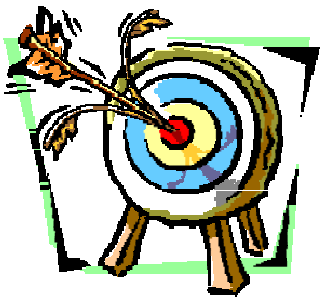
108	25	12.54	20.94	6.6	4.5	31.75	7.95	15.23	8.27	Circular
109	23.9	10.1	18.84	6.6	4.6	30.21	5.16	14.52	11.7	Circular
110	22.9	9.3	22.24	7	4	30.82	6.57	15.13	14.32	Circular
111	21.7	8.6	17.39	5.9	3.9	24.6	4.57	13.05	10.6	Circular
112	23.1	11.87	20.52	6.4	3.7	25.72	7.63	16.67	13.5	Oval
113	23.7	10.04	20.02	6.2	4.2	22.92	5.19	14.03	10.45	Oval
114	24.5	11.74	20.27	6.9	4.5	24.27	5.39	15.51	12.34	Circular
115	25.5	10.67	17.49	6	4.2	24.35	4.95	17.79	9.75	Circular
116	25.3	13.35	20.81	6.7	4.3	36.39	6.06	14.2	15.61	Circular
117	23.8	9.99	19.7	6.6	4.3	25.79	4.67	14.61	13.03	Circular
118	26.4	11.33	23.26	7.5	5.3	23.9	12.18	16	12.87	Circular
119	28.3	11.68	22.65	7.2	5	31.35	10.54	16.51	15.88	Oval
120	21.4	9.63	17.78	5.7	3.8	31	5.06	13.92	8.17	Oval
121	26.5	13.93	23.1	7.4	5.1	29.64	6.32	16.39	12.89	Circular
122	24.4	9.76	21.96	6.6	4.4	24.35	5.17	15.87	14.51	Oval
123	26.3	12.02	21.1	6.8	4.1	26.59	7.58	14.25	14.8	Circular
124	25.5	10.78	24.93	7.4	4.8	30.8	7.61	17.32	16.15	Oval
125	20.6	10.46	18.05	5.8	3.4	19.18	6.48	13.11	8.86	Circular
126	22.6	10.71	19.17	6.2	3.7	22.11	6.72	14.57	12.04	Circular
127	25.2	10.53	19.5	6.2	4	24.78	7.28	14.77	11.56	Circular
128	23.1	10.91	20.18	6.4	4.1	21.26	5.69	14.95	11.42	Oval
129	24.6	11.66	22.36	7.2	5	24.61	5.78	15.69	13.7	Circular
130	25.4	10.21	20.61	7.2	4.8	31.69	5.99	15.82	14.25	Circular
131	23.2	6.74	20.66	6.68	4.8	27.48	5.6	15.32	6.59	Circular
132	27.3	12.79	20.14	6.4	4.5	25.18	6.03	13.95	12.54	Circular
133	22.6	8.11	20.04	6.8	4.3	25.03	5.42	15.25	14.36	Circular
134	20.9	11.24	16.39	6.3	4.1	22.24	5.62	14.21	8.7	Circular
135	24.1	10.5	23.29	7.2	4.6	32.67	5.51	15.12	16.27	Oval
136	24.5	11.71	20.32	6.9	4.5	24.18	5.32	15.48	12.53	Circular
137	23	7.89	19.2	6.3	4.1	22.84	4.88	12.67	10.9	Oval
138	27.1	10.56	22.1	7.2	4.7	27.77	4.26	16.11	13.26	Oval
139	22.4	8.82	17.91	5.8	3.5	23.12	5.77	13.86	13.22	Oval
140	19.7	7.22	15.17	5	3.1	20.05	4.57	11.51	10.63	Circular
141	25.7	9.25	21.2	6.3	4.6	20.37	5.21	15.36	12.07	Circular
142	24.6	9.42	19.4	6.5	4.4	29.17	5.71	13.39	13.1	Circular
143	26	7.41	21.42	6.9	4.8	29.83	5.8	14.41	14.31	Oval
144	21.6	8.42	17.59	5.3	3.4	27.5	6.24	14.32	12.76	Circular
145	23.5	7.82	21.37	6.8	4.8	25.3	4.38	13.5	19.42	Oval
146	20.5	8.88	16.59	5.9	4.4	23.48	6.57	15.92	5.91	Circular
147	28.1	11.42	22.45	7.1	4.8	31.15	10.39	16.37	15.68	Oval
148	22.3	10.5	18.87	6.1	3.5	21.99	6.51	14.35	12.1	Circular
149	18.6	8.66	19.9	6.2	4.3	20.49	10.3	13.41	7.72	Oval
150	24.4	11.56	19.49	6.3	4.8	26.7	6.32	17.18	12.3	Circular
151	26.5	11.25	20.11	6.2	4.2	26.92	6.09	17.22	10.5	Circular
152	21.8	8.58	17.81	5.4	3.5	27.1	6.22	13.99	12.81	Circular
153	25.4	9.55	20.62	6.4	4.5	29.1	5.82	15.66	12.61	Oval
154	22.6	11.12	20.09	6.3	4	24.95	5.1	15.08	11.42	Oval
155	24.7	9.4	18.85	5.9	3.9	20.85	4.65	15.1	11.18	Oval

RIGHT SIDED RADIUS BONES										
S.NO.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
1	24.5	9.26	16.01	5.4	4.1	23.08	7	14.74	15.8	CIRCULAR
2	21.7	9.86	18.04	7.1	4.1	22.66	7.68	16.76	13.62	CIRCULAR
3	21	9.57	15.83	5.2	3.8	21.38	7.34	14.98	8.16	CIRCULAR
4	23.6	7.7	17.4	6.4	4.5	20.75	8.52	15.52	11.86	CIRCULAR
5	25.5	7.83	22.15	7.9	4.8	18.25	8.06	16.04	15.55	CIRCULAR
6	23.9	7.25	16.97	5.6	3.8	21.75	7.14	16.68	11.42	CIRCULAR
7	22.8	8.42	17.6	6.2	4.1	21.16	6.22	17	8.06	CIRCULAR
8	28.5	9.78	21.9	7.1	4.6	25.32	9.54	17.95	15.8	CIRCULAR
9	26.6	7.36	19.56	6.4	4.2	24.31	5.22	16.88	20.31	CIRCULAR
10	25	10.47	21.78	6.5	4.5	27.77	9.99	15.95	12.69	CIRCULAR
11	24	7.8	21.79	6.8	4.2	25.2	4.57	17.82	12.61	CIRCULAR
12	24.8	10.88	20.78	6.5	4.3	23.38	8.9	15.59	12.56	CIRCULAR
13	23.2	9.63	18.58	6.2	3.7	20.4	4.9	14.17	14.2	CIRCULAR
14	23.8	9.74	20.53	6.4	5	22.38	4.77	16.4	11.41	CIRCULAR
15	24.1	10.92	20.52	6.3	4.9	39	6.78	13.95	6.39	CIRCULAR
16	23.8	8.29	16.2	5.3	3.9	31.85	4.13	14.8	11.22	CIRCULAR
17	24.7	8.26	21.21	7.5	5.1	27.16	5.24	13.89	14.98	OVAL
18	21.2	9.81	19.87	6.4	3.7	23.92	5.92	14.28	8.25	OVAL
19	27.5	9.92	22	7	4.6	35.86	8.57	13.54	14.23	CIRCULAR
20	24.4	7.9	23.22	7.5	5	33.78	7.4	13.8	17.4	CIRCULAR
21	24.8	9.72	21.86	7.3	5	25.7	6.04	15.58	11.48	CIRCULAR
22	20.4	4.88	15.26	4.6	2.9	17.97	5.13	10.54	12.56	CIRCULAR
23	22.2	8.45	17.93	6	3.6	24.87	5.24	13.48	12.28	CIRCULAR
24	25	9.33	18.85	5.8	4.4	28.79	4.71	12.93	10.96	OVAL
25	25	7.67	18.63	6	4	23.28	5.82	15.2	14.81	CIRCULAR
26	21	7.26	18.79	5.9	3.6	16.14	5.63	11.12	12.07	CIRCULAR
27	25	8.94	19.68	6.1	4.3	22.89	5.24	14.18	12.56	CIRCULAR
28	22.9	8.48	18.32	6.3	4	18.52	5.21	14.96	10.35	CIRCULAR
29	23.7	7.69	21.79	7.1	4.5	25.88	5.56	15.83	12.6	CIRCULAR
30	20.1	7.48	16.75	5.5	2.9	15.73	4.39	13.16	11	CIRCULAR
31	23.7	7.46	20.94	6.8	4.6	29.4	3.54	14.41	17.7	CIRCULAR
32	22.7	8.33	22.4	7.1	4.2	25.81	7.46	15.73	11.71	OVAL
33	23	8.54	21.61	6.6	4.9	39.7	6.14	16.81	9.56	CIRCULAR
34	23.2	8.69	18.74	7.1	4.2	25.19	4.58	14.07	10.38	CIRCULAR
35	25.4	8.46	20.5	6.9	4.9	25.82	4.42	15.24	13.68	CIRCULAR
36	23.9	7.64	18.5	6	4.1	33.98	5.21	14.44	14.57	CIRCULAR
37	22.3	7.18	17.09	5.5	3.2	27.05	6.32	13.94	11.72	OVAL
38	21	6.72	17.61	5.5	4.3	19.62	3.94	14.19	13.37	CIRCULAR
39	22.7	5.87	19.55	6.4	3.3	27.23	5.97	16.8	10.08	CIRCULAR
40	24.6	7.56	21.27	6.9	4.6	32.97	4.62	16.62	11.8	OVAL
41	24.2	8.62	20.99	6.7	4.5	28.59	5.73	15.53	13.74	CIRCULAR
42	22.2	9.66	19.4	6	4	29.68	3.51	15.06	13.7	OVAL
43	19.5	8.79	17.82	5.7	3.7	19.72	5.3	13.9	11.86	OVAL
44	21.6	8.47	19.49	6	3.7	26.63	7.01	15.33	10.12	OVAL
45	22.4	8.95	17.74	5	3.7	23.99	5.84	14.83	9.42	CIRCULAR
46	22.1	9.14	20.64	6.5	3.8	23.31	4.6	15.56	16.52	OVAL
47	24.6	10.33	19.87	6.3	4.1	39.53	10	14.75	13.55	CIRCULAR
48	21.8	8.75	16.35	5.3	3.7	21.68	5.9	11.96	11.73	CIRCULAR
49	21.4	8.28	17.9	5.6	3	26.89	4.26	13.18	12.68	CIRCULAR
50	24.2	8.66	18.56	5.9	4.1	22.67	6.08	14.47	14.48	CIRCULAR
51	24.5	9	18.45	5.9	4.4	29.02	4.73	15.26	13.63	OVAL
52	22.9	8.13	20.28	6.1	3.9	21.45	4.07	16.85	13.82	OVAL
53	24.4	8.75	19.36	5.9	3.5	23.26	6.27	12.66	11.71	OVAL
54	20.4	6.81	15.07	4.9	3.2	20.54	4.63	13.3	13.72	OVAL
55	21.6	7.1	15.48	4.9	3	17.29	6.74	10.57	11.14	OVAL

56	24.4	8.43	20.08	6.4	3.6	25.89	5.34	16.48	13.39	OVAL
57	24.1	8.58	19.98	6.4	3.7	26.47	5.87	14.14	13.22	CIRCULAR
58	21.2	10.21	18.38	5.9	3.6	22.14	6.19	14.22	7.52	CIRCULAR
59	25.2	9.39	18.87	6.4	4.4	22.21	4.55	14.36	13.29	CIRCULAR
60	22.3	8.19	17.81	5.5	3	26.93	5.3	13.96	12.04	CIRCULAR
61	22.3	8.7	16.54	5.6	3.7	20.05	4.52	14.2	12.33	CIRCULAR
62	26.7	9.58	18.89	6.3	4.4	23.25	5.24	14.74	17.7	CIRCULAR
63	23.7	9.66	24.66	7.5	4.6	21.36	7.79	15.66	15.62	CIRCULAR
64	24.4	7.95	18.2	6.1	4.1	20.4	5.73	15.54	14.62	CIRCULAR
65	26.5	8.3	21.29	7	4.8	24.53	9.25	18.69	16.48	OVAL
66	27	9.69	21.16	6.3	4.7	24.24	10.56	19.62	15.85	CIRCULAR
67	25.6	8.6	20.2	6.5	4.7	18.89	6.85	15.5	16.4	CIRCULAR
68	22.9	9.86	19.64	6.1	4.4	31.15	5	13.26	10.89	CIRCULAR
69	25.5	10.98	22.97	7.1	4.5	31.56	4.82	16.57	14.26	CIRCULAR
70	24.9	9.49	21.44	7	4	21.96	5.99	12.69	15.64	OVAL
71	21.9	8.45	18.36	5.5	3.9	39.18	6.53	13.18	10.84	CIRCULAR
72	22.2	8.6	17.53	5.9	3.5	21.43	7.54	13.94	9.23	CIRCULAR
73	23.5	8.88	20.45	6.5	4	23.84	7.57	15.05	9.63	CIRCULAR
74	22.4	8.58	17.62	6	3	15.41	6.51	12.3	8.91	OVAL
75	25	10.27	19.13	6.9	4.4	22.39	5.5	16.72	12.04	CIRCULAR
76	25.8	10.83	23.5	7.5	4.9	25.63	8.21	16.95	11.44	CIRCULAR
77	26.9	10.44	23.71	7.6	4.4	29.78	8.01	17.24	14.08	OVAL
78	24.9	9.95	21.51	7.1	4.8	28.08	7.98	16.96	9.01	CIRCULAR
79	24.7	10.54	21.6	6.9	4.1	23.01	6.21	17.08	12.64	OVAL
80	26	10.73	20.3	6.7	4.1	28.05	7.55	16.43	14.37	CIRCULAR
81	21.9	8.03	20.1	6.5	4.8	25.36	7.34	15.11	13.81	OVAL
82	24.9	10.5	18.71	6.2	4	23.58	5.1	14.75	13.67	OVAL
83	24.4	9.26	22.6	7.1	4.4	23.99	7.32	15.59	13.71	CIRCULAR
84	23.7	11.46	21.5	7	4.2	22.58	8.91	14.9	9.37	CIRCULAR
85	22.6	10.11	19.4	6.3	3.7	21.23	6.39	13.8	12.19	CIRCULAR
86	20.1	7.51	18.5	5.7	3.1	22.72	5.25	13.51	13.12	CIRCULAR
87	23.6	9.84	21.81	6.3	3.5	22.46	5.96	16.73	15.93	OVAL
88	24.5	9.86	19.42	5.9	3.6	23.9	7.79	17.08	11.46	CIRCULAR
89	26.1	9.54	18.65	6.9	4.2	27.31	7.81	16.55	12.07	CIRCULAR
90	22.6	10.84	19.35	6.5	4.6	21.9	5.21	13.49	11.54	CIRCULAR
91	26.4	12.06	22.86	7.4	4	25.67	8.06	17.21	13.58	OVAL
92	25.9	10.4	22.12	7	4.3	23.31	5.31	15.55	11.33	OVAL
93	21.9	9.93	18.75	6.1	3.7	22.15	6.62	12.42	10.57	OVAL
94	24	10.16	20.56	6.4	4	27.85	6.1	14.59	13.67	OVAL
95	22.4	10.14	18.01	6.1	3.7	23.92	5.4	15.31	10.96	CIRCULAR
96	25.1	11.02	20.04	6.6	3.9	28.11	7.72	14.85	16.17	CIRCULAR
97	26.7	11.46	21.22	6.6	4.1	27.87	5.57	15.89	14.75	OVAL
98	22.7	12.16	20.05	6.5	4	25.01	5.84	16.13	9.81	OVAL
99	23.7	9.68	20.43	6.4	4	25.01	4.48	15.63	10.41	OVAL
100	23.3	10.1	23.74	7.4	4.3	22.97	6.38	15.29	4.84	CIRCULAR
101	23.6	10.01	21.13	6.6	4.1	27.47	5.99	16.79	13.21	CIRCULAR
102	22	8.43	18.24	5.6	3.7	40	6.98	13.2	10.84	CIRCULAR
103	23.5	11.44	21.55	6.6	5	29.77	6.96	15.1	13.71	CIRCULAR
104	21	10.56	17.77	5.4	3.7	26.07	6.33	13.23	12.36	CIRCULAR
105	24.9	11.06	22.17	6.9	4.5	26.79	7.14	14.27	13.38	CIRCULAR
106	23.2	9.7	21.48	6.9	4.1	26.31	6.19	15.4	15.14	CIRCULAR
107	21	10.88	19.4	6.2	4.2	19.79	6.21	13.7	8	CIRCULAR
108	23.5	9.66	20.78	6.5	4.2	24.05	6.9	17.18	13.98	OVAL
109	24.7	11.9	22.63	7.2	4.3	33.29	4.82	15.41	12.6	CIRCULAR
110	23.9	11.37	19.86	6.5	4	29.91	7.01	16	10.77	CIRCULAR
111	26.6	9.17	21.09	6.4	4.5	24.53	6	17.54	16.33	OVAL
112	26.9	11.9	21.98	7	3.9	29.65	7.21	14.71	14.03	OVAL

113	25.1	10.24	20.19	6.3	4.3	26.07	9.28	15.34	14.08	OVAL
114	25.9	10.93	22.71	7	4.1	25.25	5.72	16.35	14.9	OVAL
115	24.5	12.66	21.63	6.6	4	25.3	5.16	16.8	13.5	OVAL
116	24.6	9.54	20.96	6.8	3.6	25.03	5.13	15.29	12.48	CIRCULAR
117	25.2	10.08	23	7.1	4.3	22.1	5.83	14.36	10.18	OVAL
118	24.2	9.62	19.89	6.3	3.9	29.41	5.67	13.6	16.65	OVAL
119	26.3	10.79	22.07	7	4.5	25.4	4.93	16.54	11.69	OVAL
120	23.7	7.8	17.2	6.3	4.2	21	8.5	15.1	11.72	CIRCULAR
121	26.4	7.24	19.35	6.2	3.97	24.52	5.7	16.42	20.17	CIRCULAR
122	24.6	9.3	16.15	5.7	4.3	23.22	7.2	14.8	15.9	CIRCULAR
123	21.3	9.56	17.34	6.3	3.9	21.96	7.45	15.7	11.52	CIRCULAR
124	25.2	10.9	18.97	6.6	4.5	24.2	5.4	14.5	13.92	OVAL
125	25.9	10.8	23.7	7.2	5.1	25.49	8.11	17.1	11.25	CIRCULAR
126	22.9	12.3	20.85	6.6	4.1	25.3	5.99	16.42	9.79	OVAL
127	25.6	10.85	23.1	7	4.7	31.69	4.81	16.7	14.36	CIRCULAR
128	27.6	9.9	21.8	7.2	4.5	35.82	8.55	13.5	14.27	CIRCULAR
129	20.3	4.85	15.24	4.5	2.8	17.95	5.1	10.49	12.53	CIRCULAR
130	24.2	10.95	20.6	6.2	5.1	38.98	6.67	13.92	6.4	CIRCULAR
131	21.8	10.42	18.9	6.1	3.8	22.56	6.45	14.7	7.99	CIRCULAR
132	23.1	8.22	20.36	6.2	4	21.63	4.11	16.82	13.91	OVAL
133	19.7	8.8	17.91	5.8	3.8	19.68	5.25	13.83	11.81	OVAL
134	22.8	5.9	19.6	6.5	3.2	27.39	5.89	16.9	10.2	OVAL
135	24.4	9.16	20.19	6.5	3.7	26.52	5.95	14.26	13.31	CIRCULAR
136	21.5	10.39	18.45	6.1	3.7	22.2	6.41	14.38	7.79	CIRCULAR
137	23.2	9.98	23.42	7.3	4.2	22.71	6.24	15.13	4.62	CIRCULAR
138	25.4	10.1	21.98	6.8	4.2	23.09	5.22	15.36	11.29	OVAL
139	26.3	11.21	21	6.3	4	27.5	5.32	15.75	14.5	OVAL
140	24.5	7.49	21.17	6.8	4.6	32.82	4.56	16.51	11.8	OVAL
141	20.2	7.56	16.89	5.5	3.1	15.89	4.5	13.26	11.1	CIRCULAR
142	22.5	8.18	22.25	6.9	4.1	25.64	7.44	15.61	11.42	OVAL
143	27.2	9.8	21.3	6.4	4.9	24.75	10.99	19.1	15.89	CIRCULAR
144	23.5	9.42	24.45	7.5	4.5	21.22	7.56	15.45	16.42	CIRCULAR
145	25.4	8.5	20.11	6.4	4.8	18.66	6.67	15.29	16.22	CIRCULAR

Introduction



Aims & Objectives

Review of Literature

Methodology

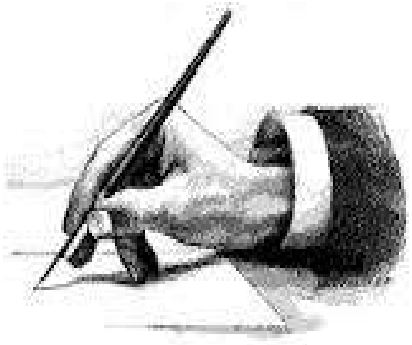
Results

Discussion

Conclusion

Summary

Bibliography



Annexure-I

Annexure-II

Annexure-III

Annexure-IV