GLENOID MORPHOMETRY IN A KENYAN POPULATION

WITH

RELEVANCE TO SHOULDER ARTHROPLASTY

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DEPARTMENT OF ORTHOPEDIC SURGERY

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DECLARATION

This dissertation is my original work and has not been submitted for a degree in any other University. Where other peoples' work or my own work has been used, this has properly been acknowledged ana referenced in accordance with the with the University of Nairobi plagiarism policy.

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DEDICATION

I dedicate this study to my loving family: my parents Anne Muthoni Kimani and Francis Kimani, my brother Bobby Njoroge, and my partner Dr. Boniface Kairu Githaiga. For their unwavering support, love, understanding and encouragement during my period of study. Without them this work would not have been possible.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RSA……………………………….Reverse Shoulder Arthroplasty

TSA……………………………….Total Shoulder Arthroplasty

KNH……………………………...Kenyatta National Hospital

UON……………………………...University of Nairobi.

ERC……………………………….Ethics and Research Committee

CT………………………………...Computed Tomography

MRI……………………………….Magnetic Resonance Imaging

SPSS……………………………. Statistical Package for Social Sciences

3D………………………………. Three Dimensional

SD………………………………. Standard Deviation

ABSTRACT

Background: A basic understanding of the glenoid anatomy and the various variations in different populations is critical in glenoid resurfacing and optimal utilization of glenoid components. The glenoid measurements that are crucial in shoulder replacement are glenoid height, glenoid width, glenoid inclination, and glenoid version angles.

Shoulder replacement surgery has been used successfully for the treatment of degenerative conditions around the glenohumeral joint to restore normal joint movement.

The aim of replacement surgery is to restore the native shoulder complex kinetics. It is therefore important to understand the native morphology of the articulating surfaces as it gives guidance in selection of suitable endoprosthesis while restoring the native biomechanics of the joint.

Several cadaveric studies done have shown a considerable natural variability in the glenoid parameters. This variability affects design of prosthesis, instrumentation techniques and intraoperative implantation of the glenoid components

Recognition of various patterns of glenoid wear is important in preoperative surgical planning in patients undergoing shoulder arthroplasty.

Study objective: To determine the glenoid morphometry in a Kenyan population with relevance to shoulder replacement.

Materials and methods: An osteological cross-sectional study consisting of one hundred and fifty scapulae derived from the Osteological collection of the National Museums of Kenya. Ethical approval was sought from The University of Nairobi and Kenyatta National Hospital, Ethics and Research Committee (KNH/UON-ERC).

The scapulae bones were identified coded and sexes differentiated, the glenoid width and height were measured and recorded in millimeters (mm) using digital Vernier calipers while the glenoid version and inclination angles were measured and derived using a protractor and a geometric triangle.

Data analysis: The data were compiled and analyzed using IBM Corp. Statistical Package for the social sciences (SPSS) for windows, version 25. Comparison of the mean data of the respective measurements i.e. glenoid inclination, version, glenoid height, and width according to sex was analyzed using the unpaired t-test. Summary of the data will be stated as mean (SD). Statistical significance was defined as P<0.05 for a 95% confidence interval.

Results: A total number of 150 dry scapulae bones were analyzed with males' scapulae 119(79.3%) and 31 females (20.7%).

For both sexes the mean glenoid maximum height was 35.96mm±2.88 **(**28.43-43.23mm) and glenoid width was 23.97mm±2.26 **(**18.02 - 30.50mm) with significant sex dimorphism. In Males the mean glenoid height was 36.58mm±2.61 while in females 33.50±2.66mm.

the glenoid height on the right in males 36.80mm±2.65 and left 36.35mm±2.57 and in females glenoid height on the right33.22mm±2.33 and left 33.73mm±2,96 with significant differences between both sides and in both sexes. In males the mean glenoid width 24.52mm±2.0 and in females 21.80mm±2.66 with significant sex differences. in males the glenoid width on the right 24.74±2.02mm and the left 24.29±1.98mm while in females right 21.89±1.85mm and the left 21.73±2.01mm. The average inclination angle was 6.0°interquartile range 6° to 7°. The average anteversion /retroversion angle from male and female dry bones was -1.0°±4.0° (-3°-6°).

Conclusion:

The glenoid size in our population is significantly smaller compared to other populations. The glenoid height and glenoid width were significantly smaller compared to studies done in Europe and the United States. The glenoid width and the height are crucial in estimating the suitable size of the glenoid components as well as the optimal size of the glenoid baseplates.

The glenoid inclination in the Kenyan population was noted to be mean of 6° and the glenoid in our population is mostly retroverted and this serves as a guide in implant positioning of the glenoid components to prevent superior migration of the humerus and ensuring optimum implant fixation.

1.INTRODUCTION

1.1 Background

An understanding of glenoid anatomy is relevant to shoulder replacement surgery. Shoulder replacement surgery aims in restoring the native anatomical relationships of the glenohumeral joint.

The anatomical parameters of the glenoid crucial to preoperative planning of patients include glenoid height, glenoid width, glenoid inclination, and glenoid version. Several cadaveric studies done have shown significant variations in these parameters in various populations(1–4). These variabilities affect prosthesis design, instrumentation, and intraoperative implantation techniques.

Achieving stable fixation of the glenoid is one of the primary goals of shoulder replacement surgery, however the low strength of the glenoid vault and various wear patterns present key limitation in securing fixation of glenoid components.

Shoulder arthroplasty surgery is a successful procedure with reported improved shoulder function and pain relief where the glenohumeral articulating surfaces has been destroyed by infectious, degenerative disease, or trauma. Since the introduction of shoulder replacement surgery in 1892, numerous studies done continue to show significant improvement in pain relief and overall shoulder function(5–7).

Shoulder replacement surgery has undergone immense evolution over the past decades with increasing use of reverse shoulder arthroplasty(rTSA) surpassing anatomic shoulder arthroplasty (aTSA) and hemiarthroplasty(HA) in trauma patients(8).

Evolution of the shoulder prosthesis has led to the introduction of glenoid resurfacing with glenoid components which has served to provide a fulcrum and better excursion in patients with glenoid wear(9,10). However the procedure does have complications including: rotator cuff tears, glenohumeral instability, glenoid component aseptic loosening and wear, inferior glenoid notching and periprosthetic humeral fractures (11).

Aseptic loosening of the shoulder endoprosthesis is a common cause of total shoulder arthroplasty failure. This can be as a result of aseptic osteolysis or rotator cuff insufficiency due to failure in achieving soft tissue tension with resultant instability .The end result is significant glenoid bone loss requiring glenoid reconstruction with bone grafting the deficient glenoid or eccentric glenoid reaming(12,13).

Severe glenohumeral osteoarthritis has been associated with glenoid posterior wear, osteophytes and posterior displacement of the head of the humerus with a mean glenoid retroversion of 11° and (range 2°-32° retroversion) as compared to healthy patients with a mean retroversion 2° (14° anteversion-12° retroversion)resulting in significant alteration of the native glenoid anatomy(14)

The glenoid measurements have previously been assessed radiologically using plain radiographs, two-dimension Computed tomography scans (CT) However there has been errors particularly during patient positioning particularly in obtaining the recommended views in plain radiography(15). In addition, CT scans and MR imaging may not always be available and are technically demanding with a steep learning curve not to mention the added expense to the patient

1.2 Problem Statement

Shoulder replacement surgery is commonly indicated for degenerative conditions involving the glenohumeral joint. The aim of the surgery is restoring the normal kinetic of the shoulder joint. To achieve this the orthopedic surgeon, requires an in depth understanding of the glenoid parameters relevant to shoulder arthroplasty.

1.3 Study Question

What are the glenoid morphometric measurements relevant to shoulder arthroplasty in our Kenyan population?

1.4 Main Objective

To determine the glenoid morphometry in a Kenyan population

1.5 Specific Objectives

1. To determine the glenoid width,
2. To determine the glenoid height,
3. To determine the glenoid inclination and,
4. To determine glenoid version angles in the Kenyan population.

1.6 Study Justification and Significance

The significant natural variability of the glenoid parameters required for shoulder replacement surgery as demonstrated in different cadaveric studies often affects the prosthesis design and intraoperative instrumentation and implantation techniques.

There is paucity of data of the glenoid morphometry with relevance to shoulder arthroplasty in the Kenyan population this study serves as a guide in understanding the glenoid anatomy in the Kenyan population.

2. LITERATURE REVIEW

2.1Background

Shoulder arthroplasty has demonstrated significant improvement in shoulder function and pain relief where the glenohumeral articulating surfaces have been destroyed by infection, arthritis, or trauma. The history of shoulder replacement surgery dates to 1892 when Jules Emile Péan a French orthopedic surgeon first implanted rubber and platinum implants in a shoulder destroyed by tuberculous arthritis. He noted significant pain relief and improved function however the infection recurred and the prosthesis had to be removed two years later(7).

In 1955, Charles Neer introduced a humeral head prosthesis for patients with complex proximal humerus fractures called Neer I while leaving the glenoid bone intact and reported significant pain relief(16). In 1974 a modification of the humeral head was introduced which was designed to conform to a resurfacing polyethylene glenoid endoprosthesis called Neer II, introducing total shoulder arthroplasty. This served to provide a fulcrum and better excursion in patients with glenoid wear. This was initially used in the treatment of glenohumeral degenerative disease and the patients reported significant reduction in pain and restoration of significant shoulder function whereas some patients exhibited slow recovery and fatigability(9,10).

Glenoid components were previously fixed non-cement less using screws and a porous coating on the metal backing with an accompanying polyethylene cup. This was later replaced by using polyethylene and polymethyl methacrylate. However the high failure rate is increased with glenoid component loosening, emphasis is now placed on restoring normal kinematics of the glenohumeral joint by achieving the normal anatomical orientation of the glenoid articular surface, soft tissue balancing and stabilization of the shoulder physiologically(17).

The pathologies indicated for glenoid resurfacing include: glenohumeral osteoarthritis and inflammatory arthritis(10,18) resulting in incongruous glenohumeral articular surfaces. An intact rotator cuff muscles, and adequate bone stock on the glenoid is required for a successful shoulder replacement surgery.

Preoperative planning for shoulder arthroplasty includes routine plain radiography and computed tomography (CT). These aid in assessment of the osseous structure for instance the glenoid inclination and version. In addition to that Magnetic resonance imaging (MRI) is useful in evaluating the status, integrity, and the extent of fatty degeneration of the rotator cuff muscles.

Preoperative assessment of the glenohumeral joint is important in templating the prosthetic components prior to surgery(8,9,10).However there were reports on interobserver reliability in the accuracy of the implant selection versus preoperative chosen component sizes (23).

Anatomy of the glenohumeral joint and biomechanics

Motion

The glenohumeral joint is a synovial joint made up of an osseous non-conforming glenoid, articulating with the head of the humerus, the glenoid labrum increases the conformity of the articulation. It exhibits both rotational movements and translatory movements of the head of the humerus(24).

The ratio of the head of the humerus radius and the radius of the glenoid cavity articular surface exhibit high level of conformity with the humeral head being more convex in a ventral-dorsal direction. Studies done on humeral head measurements concluded that the humeral head articular surface can be approximated to a sphere(25). This concludes that motion in this joint represents a ball and socket(24).

In normal shoulders the superior-inferior translation of the head of the humerus is 0.3 to 0.35 mm during active and passive motion. However, the ventral-dorsal translation is larger with the humeral head bearing an anterior translation of 3.8mm during flexion and 4.9mm during extension. This is as a result of the anatomic configuration of the glenoid being more concave in the superior-inferior direction (radius 32.3 ±7.6 mm) as compared to the ventral-dorsal direction (radius 40.6 ±14mrn)(2,24). During active motion, the humeral head translation is lesser than during passive motion.

The joint reaction forces taken from a three dimensional model analyzing the load distribution between the muscles, ligaments and the osseous component indicated a resultant force of 650Newtons with 60° shoulder abduction(26) .

Ligaments

The capsuloligamentous structures are the primary static stabilizers of the shoulder. They are generally lax to allow a great range of motion and tense at extremes of motion.

The superior glenohumeral ligament in conjunction with the superior anatomical tilt of the glenoid limit's translation of the head of the humerus inferiorly and rotation of the adducted arm externally.

The middle glenohumeral ligament is taut in external rotation and about 45 degrees of abduction hence a primary stabilizer of anterior translation and a secondary stabilizer to external rotation during shoulder abduction and inferior translation during adduction.

Superior migration of the head of the humerus is seen both partial and full thickness tears of the rotator cuff and chronic anterior shoulder instability. This is typically noted during elevation of the arm caused by muscle imbalance of the deltoid muscle and the weak rotator cuff muscles. This results in significant alterations in the glenohumeral kinematics(24).

Muscles

Muscles act as dynamic stabilizers of the shoulder by several mechanisms: muscle contraction with a net resultant compression of the articulation surfaces(27,28), wide range of motion in the joint that passively tightens the capsuloligamentous structures, net direction of joint reaction forces to the central glenoid surface by coordinated synchronous muscle action and the passive muscle tension.

The rotator cuff muscles especially the subscapularis muscle is demonstrated as both the active and passive stabilizer anteriorly with equal contributions from the supraspinatus, infraspinatus, and teres minor muscles of the abducted shoulder. The subscapularis also acts as posterior stabilizer of the shoulder with the arm in 90° flexion. The rotator cuff muscles function together with resultant coupled forces of the deltoid muscle and supraspinatus acting as elevators in the frontal plane and the teres minor and the infraspinatus as depressors

2.2 GLENOID ANATOMY

The glenoid orientation is very important as it plays a crucial role in maintaining the normal shoulder biomechanics as well as assessing resultant functional outcomes of TSA. It is important to understand the variations crucial in proper utilization of glenoid components in shoulder arthroplasty.

The glenoid is a pear-shaped bone part of the scapular bone located on its lateral border, it is tilted superiorly 10-15°relative to the medial border, superiorly it has the supraglenoid tubercle which provides the origin of the long head of the biceps muscle and inferiorly the infraglenoid tubercle giving origin to the long head of triceps muscle(24).

The glenoid forms the glenoid fossa which articulates with the head of the humerus. It is oriented laterally and anteverted or retroverted typically less than 10° in either direction with a long vertical diameter approximately 35mm and width of 24mm.

The glenoid cavity is covered with articular cartilage and provides attachment to the fibrocartilaginous glenoid labrum which serves to deepen the cavity by 50% and helps generate the vacuum effect thus increasing the stability and congruency of the glenohumeral joint. It is estimated that the glenoid covers 20-25% of the humeral head, it is relatively shallow allowing greater range of motion.

Measurements of the glenoid relevant to shoulder arthroplasty include glenoid inclination, version, height, width, shape, and size of the vault. Variations in these parameters affects prosthesis designs and sizing, instrumentation, and surgical implantation process. Proper glenoid prosthesis placement has a direct effect on clinical outcome of patients and is therefore crucial to restore the anatomy(1,29).

2.2.1 Glenoid Width

Glenoid width is the distance between the most ventral and the most dorsal points on the glenoid surface. Glenoid width is a function of the glenoid overall shape which has mostly been described as pear-shaped, elliptical or oval(1)

This measurement is often influenced by presence of osteophytes as well as glenoid bone loss. This gives the shape of the glenoid as denoted on measurements of the upper width and the lower width. Various shapes have been described from different studies with a majority being pear-shaped or inverted comma narrow superior aspect and broader inferior aspect compared to an elliptical or oval glenoid, which has a broader middle portion(30). Average width measured in both sexes was 27.8mm± 3.1mm. In males 30.3 mm ± 3.3 while in females width 26.2 mm ± 1.6 a study done by Mathews el al and Churchill et al(4,31).

Glenoid width is crucial in determining the glenoid component size with an effort to prevent glenoid overhang.

2.2.2 Glenoid Height

Glenoid height is the distance between the supraglenoid and the Infra glenoid tubercle. A cadaveric study by Checron et al reported a mean height of 37.9mm (30). A study by Mathews et al reported a mean height of 36.6 mm ± 3.6 in both sexes. Also noted significant differences in both sexes. In males glenoid height 39.5 mm ± 3.5 while in the females a glenoid height 34.8 mm ± 2.2 was measured(4).

Iannotti et al reported a mean of 39mm while Churchill reported a mean height of 37.5mm for men and 32,6mm for women(31,32).

Glenoid height assists in determining the glenoid component size during implantation in shoulder arthroplasty.

2.2.3 Glenoid inclination

Glenoid inclination is described as the orientation of its articular surface in relation to the superior to inferior scapular axis. The average superior inclination is 4 degrees (7°-15.8°in male specimens) and 4.5° (1.5°-15.3°in female specimens) with a varied range of inclination between 7° of inferior tilt to 15.8° superior tilt. It was also noted that Caucasian patients had a slightly greater inclination (mean of 4.6°) than African patients (mean 3.9°)(31).

It is important to appreciate glenoid inclination as placement of the glenoid component with a superior tilt during implantation has been associated with proximal humeral head migration and associated rotator cuff dysfunction following total shoulder arthroplasty(33,34)

2.2.4 Glenoid Version

Glenoid version is the angle formed from the articular surface orientation relative to the scapular transverse axis. An anterior angle is referred to as an anteversion while a posterior angle is retroversion. A study by Churchill et al recorded with an average of 1.23° of retroversion and 0.20° and 2.65° of retroversion.

The glenoid version for African and Caucasian men was 0.11° and 2.87° of retroversion respectively while that for African and Caucasian women was 0.30° and 2.16° of retroversion(31).

A study by Pipinov et al also reported that males had a larger and a more retroverted glenoid with significant variations among different ethnicities and recommended prior considerations during preoperative planning(15,16,17).

Glenoid version is most commonly calculated using axial CT scan images using the Friedman method based on the glenoid anterior and posterior axis or alternatively using the Vault method.(14). However an analysis by Matsumura et al reported that both methods of measurements had high intra and inter-observer reliability(3).

Glenoid version is important as there has been reported inferior outcomes with placement of the glenoid component in excessive retroversion(32,38).

2.2.5 DEVELOPMENT OF THE GLENOID

During growth and development, in infancy, the glenoid-coracoid interface is a contiguous, cartilaginous mass. A secondary ossification center in the superior glenoid is present and another in the inferior portion of the glenoid which are all fused by the age of 16 yrs. The glenoid cavity is concave during postnatal development with no noted significant differences in deformed shoulders e.g. Sprengel's deformity(39). During the beginning of growth spurt in adolescence shortly after 13yrs (14-15) years, a growth acceleration in the upper and middle diameters of the glenoid surface(40).

Throughout the years different imaging modalities have been used in assessing glenoid bone measurements, ranging from plain radiography, computed tomography scanning, Magnetic resonance imaging. Preoperative assessment of the glenoid is important as it gives a quantitative analysis of the glenoid bone loss. CT scan has been recommended as the modality of choice in preoperative assessment of the glenoid bone.(4,41–43)

2.3 GLENOID PATHOANATOMY

Several studies have shown aberrations of the glenoid bone anatomy associated with rotator cuff tears (mechanical plus degenerate),glenohumeral degenerative arthritis, glenoid bone dysplasia and recurrent glenohumeral instability(44)

Degenerative changes involving the glenoid vary depending on the disease process affecting the joint. Primary glenohumeral arthritis associated with glenoid wear on the posterior surface with subsequent subluxation of the humeral head posteriorly this leads to lead to posterior instability with associated internal rotation contractures(12,45). Patients with inflammatory arthritis have a tendency to develop central, symmetric glenoid erosion or anterior glenoid wear(less common) associated with cysts in the glenoid vault(46,47).

Walch description of glenoid wear

1. Type A: central wear with no posterior humeral head subluxation and minor erosion

    Type A1 has minor central wear and erosion,

    Type A2 has severe central wear and major erosion.

2. Type B: asymmetric arthritis with posterior subluxation of the head of the humerus.

3. Type B1 no obvious glenoid erosion with narrowing of the posterior joint space, subchondral sclerosis, and osteophytes.

Type B2 presence of obvious glenoid erosion with the posterior glenoid surface forming a biconcave shape.

4. Type C shows an increased glenoid retroversion angle >25 ° (dysplastic glenoid) (12,48).

Friedman et al reported asymmetric wear of the glenoid with significant osteophyte formation, large subchondral cysts as well as posterior subluxation of the humeral head. Patients with severe arthritis reported a mean glenoid orientation of 11° retroversion (2° of anteversion -32°of retroversion) while in the healthy patients the mean orientation was 2° of anteversion (14 °of anteversion to 12°of retroversion). patients with severe arthritis were noted to have increased glenoid retroversion. They therefore recommended preoperative computed tomography scan as the best modality in assessing the amount of glenoid wear(14).

Glenoid bone loss associated with recurrent anterior shoulder instability with resultant osseous Bankart's lesions, chronic glenohumeral arthritis, post reconstruction arthropathy, glenoid dysplasia have resulted in excessive retroversion of the glenoid necessitating the need for bone grafting and asymmetric reaming in reverse shoulder arthroplasty(RSA) to improve the retroversion(38,42,49,50).

Glenoid wear has been treated with eccentric reaming or addition of bone graft with an aim to correct the glenoid version and improve fixation of glenoid components. A cadaveric study by Gillepsie et al reported that up to 10° of deformity can be safely corrected using eccentric reaming without significantly affecting the glenoid width(51).for significant glenoid wear not amenable to eccentric reaming use of augmented glenoid designs has also been proposed to improve longevity of the fixation (**Error! Reference source not found.**)

Glenoid dysplasia a rare condition characterized by failure of ossification of the postero-inferior two thirds of the glenoid as well as the scapular neck with resultant hypertrophy of the articular cartilage and glenoid labrum and variable retroversion of the glenoid (41).This leads to recurrent shoulder instability and early degenerative changed in the glenohumeral joint due to altered shoulder biomechanics(52)

In summary there is a statistical difference in glenoid version and inclination in African patients compared to Caucasian population. As indicated earlier previous measurements were done radiologically using plain radiographs which however had errors during patient positioning and obtaining the relevant views required to assess the glenoid.

There is no local data on anatomical measurements of the glenoid in our population and this study will serve as a baseline guide for glenoid component measurements and sizing for patients undergoing shoulder replacement surgery given the rising prevalence of primary osteoarthritis and rheumatoid arthritis in our population.

2.4 GLENOID COMPONENTS

The most used glenoid components included cemented pegged components and keeled components as they have been shown to provide a more stable fixation. Methods of fixation that have previously been used include: cemented, non-cemented and hybrid fixation(51).

Non-cemented fixation relies upon biologic osseointegration and mechanical interlock by screw fixation or a combination of screws or press fit pegs or both. With an aim of achieving long term bone ingrowth or on growth(53).

3. **MATERIAL AND METHODS**

3.1 STUDY SITE

A cross-sectional descriptive study conducted at the University of Nairobi Human Anatomy department and National Museum of Kenya Osteology department.

The Human Anatomy department at the University of Nairobi is responsible for most of the cadaveric dissection conducted in school of medicine and has a reserve of cadavers utilized for Human anatomy dissection and provided some of the dry scapulae required for this study.

The National museum of Kenya is the custodian to dried human bones collected throughout the years.

3.2 STUDY MATERIALS

The study involved one hundred and fifty adult human scapulae identified by a fused physis.

Inclusion criteria:

1. Adult human scapulae identified by a fused physis.

Exclusion criteria:

1. Any scapula bones with obvious gross abnormalities, fractures, or missing parts.
2. skeletally immature bones (less than 18 years of age).

Sample size

Sample size was determined using the standard deviation formula

$$n = \frac{Z^2 \sigma^2}{e^2}$$

Where

n =measure of sample size

σ =Standard deviation (3.1)(4)

e = Margin of error

Z = The value for the given confidence Interval

$$n = \frac{1.96^2 \times 3.5^2}{0.5^2}$$

148 scapulae

3.3 ETHICS CONSIDERATION

Ethical approval to conduct the study was sought from the University of Nairobi and Kenyatta National Hospital, Ethics and Research Committee (KNH/UON-ERC) and the National Museums of Kenya Osteology department.

Protection of Human Subjects

This was a cadaveric study of dry scapulae bones and the specimens were handled in accordance with the Human Anatomy Act 19 Cap 249.

a. Characteristics of study population

An anatomical study involving dry scapulae bones belonging to adults above the age of 18years.

b. Linkages to subjects

The data obtained was not linked to any human subjects. The data was coded, collected, and recorded in a data collection sheet.

3.4 Methods

3.4.1 Data collection

Following identification of various scapular bones, each bone was identified, coded, and aligned in anatomical position. A line was drawn from the supraglenoid to the infra-glenoid tubercle (height) and another line was drawn from the most ventral point on the glenoid to the most dorsal point (width).

3.4.1.1 Glenoid width

The glenoid width was measured from the most anterior edges of the glenoid rim and the most posterior edge of the glenoid.

3.4.1.2 Glenoid height

The glenoid height was measured using a digital Vernier caliper from the supraglenoid tubercle and the infra-glenoid tubercle.

3.4.1.3 Glenoid inclination and version

Using a geometric triangle placed on the dorsal surface along the spine of the scapula to the most posterior glenoid rim, another triangle was placed from the supraglenoid tubercle to the infra glenoid tubercle. The angles subtended by these two axes γ were measured and the glenoid inclination calculated formula $\alpha = \gamma - 90°$. The retroversion angle β was be measured.

The measurements were taken by one investigator to avoid intra-observer error three measurements were taken separately, and the average recorded on a data collection sheet

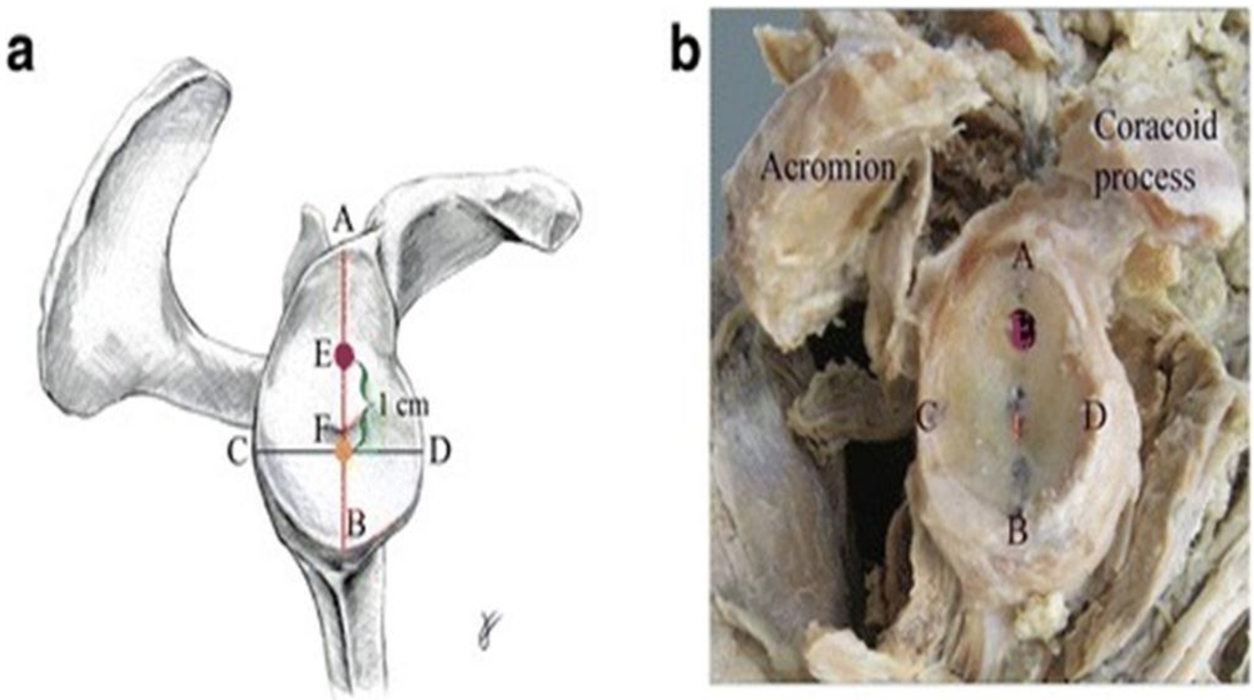

FIGURE 1 GLENOID PARAMETERS (1) GLENOID HEIGHT [AB] (2) GLENOID WIDTH [CD](33)

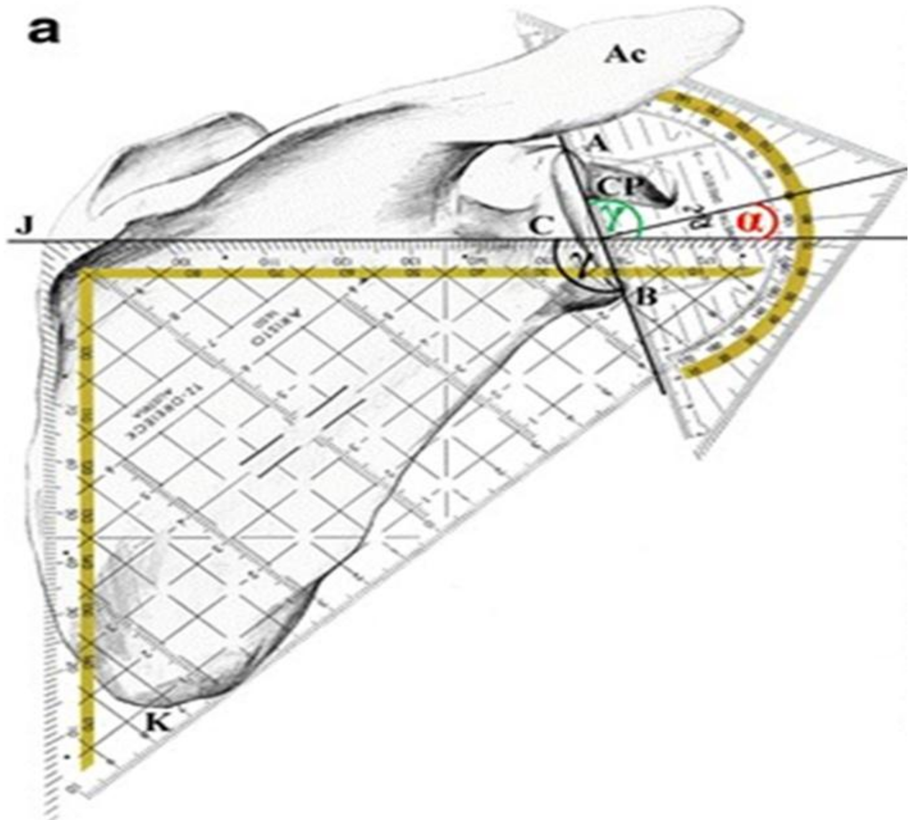

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FIGURE 2 GLENOID VERSION AND INCLINATION

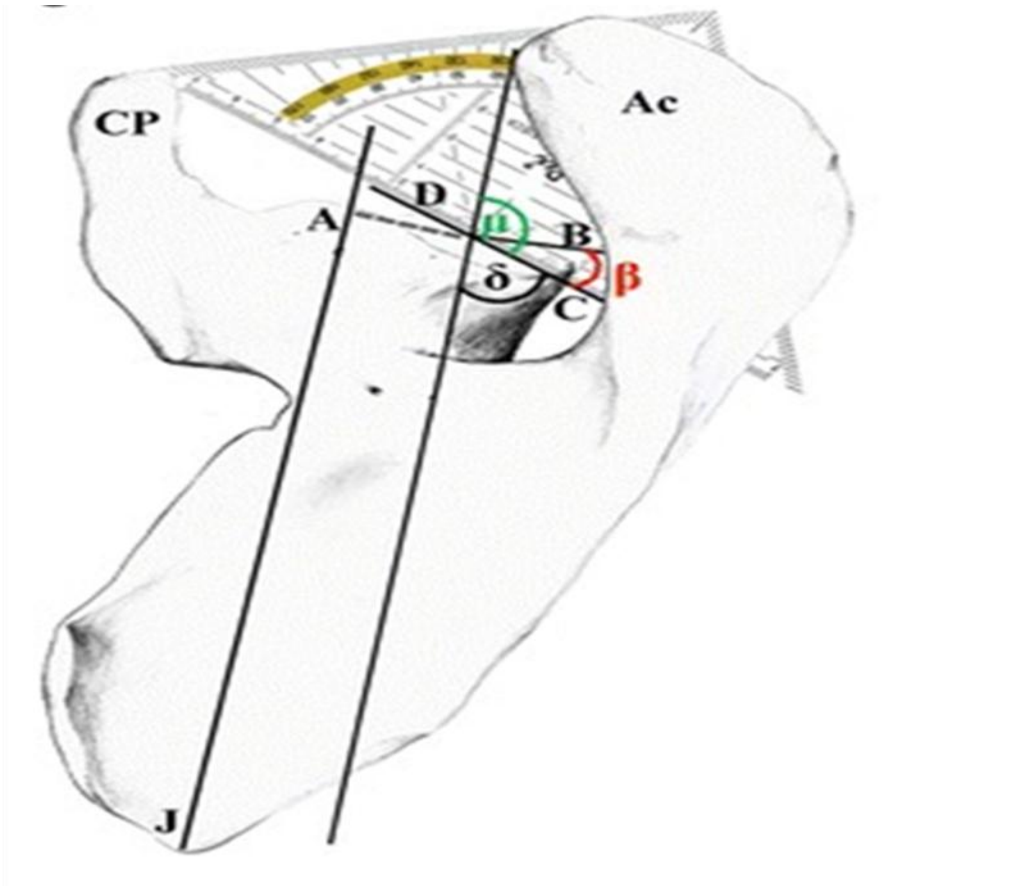


FIGURE 3 GLENOID VERSION AND INCLINATION

3.5 Data Analysis

All the data collected in this study were sorted, coded, entered and managed in Microsoft excel database. At the end of data collection, the data was exported to and analyzed using Statistical Package for the social sciences for windows, version 25.

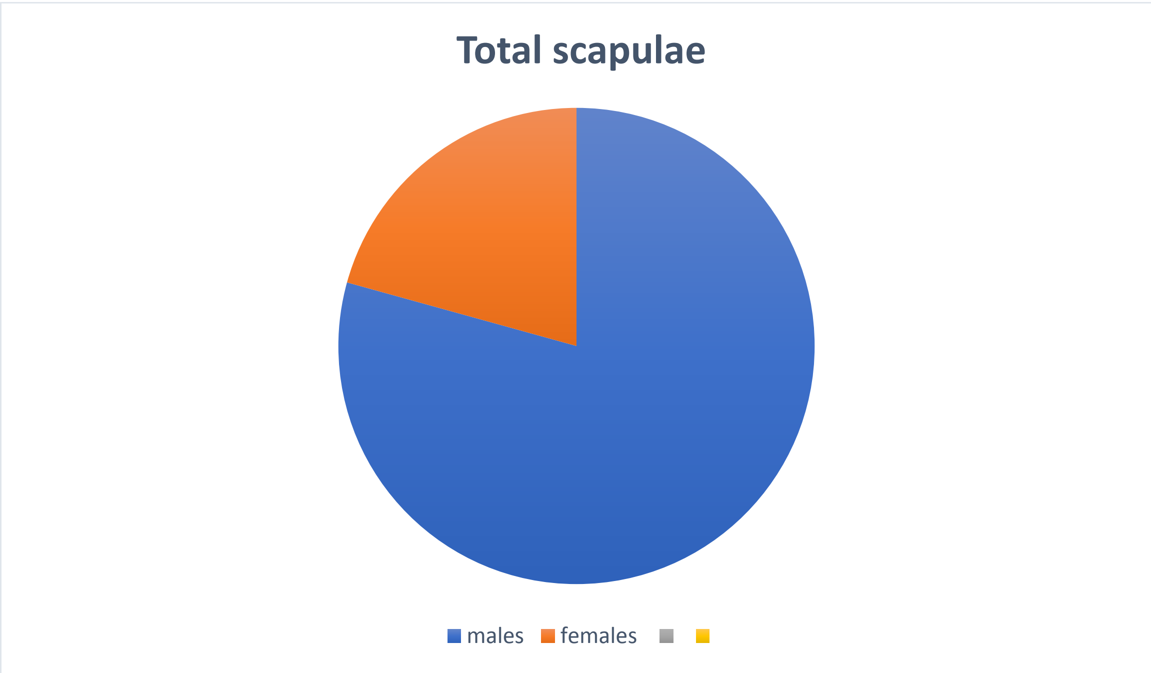
Comparisons for the mean data of the respective measurements i.e. glenoid inclination, version, glenoid height and width according to sex was analyzed using the unpaired t-test, while the correlation between the different sides of the glenoid and the sexes were analyzed using a nova test. Summary of the data was stated as mean (SD).

All Statistical tests were performed at 5% level of significance (95% confidence interval). There was no linkage to human subjects as all the specimen were coded and handled in accordance with the Human anatomy act Cap 249.

4.RESULTS

4.1 Osteometry evaluation

The total number of dry scapulae analyzed included 150 bones with males' scapulae 119(79.3%) and 31 females (20.7%).



4.2 Measurements of the glenoid cavity

4.2.1 Glenoid width

The glenoid width in both males and females was 18.02-30.50 (23.97±2.26) mm. In males (Table 1) the mean glenoid width 24.52mm±2.0 and in females 21.80mm±2.66 with significant differences ($p<0.001$) (Table 2). The glenoid width on the right 24.74±2.02mm and the left 24.29±1.98mm in males and on the right 21.89±1.85mm and the left 21.73±2.01mm $p<0.001$) in females.

TABLE 1 COMPARISON OF MEAN GLENOID WIDTH IN MALES AND FEMALES

	MEAN GLENOID WIDTH (mm)	**P-VALUE**
MALE	24.52±2.0	P<**0.001**
FEMALE	21.80±1.91	

TABLE 2 COMPARISON OF GLENOID WIDTH AND SIDES IN BOTH SEXES

SIDE	**MALE**	**FEMALE**	**P-VALUE**
RIGHT	24.74±2.02	21.89±1.85	P<0.001
LEFT	24.29±1.98	21.73±2.01	

4.2.2 Glenoid height

The glenoid height in both males and females was 28.43 to 43.23(35.96±2.88) In (Table 3) Males the mean glenoid height 36.58mm±2.61 while in females 33.50±2. 66mm.The glenoid height in males was 36.80mm±2.65 on the right and 36.35mm±2.57 on the left. The glenoid height in females on the right was 33.22mm±2.33 and 33.73mm±2.96 on the left ($p<0.001$) (Table 4).

TABLE 3 COMPARISON OF GLENOID HEIGHT IN BOTH MALES AND FEMALES

SEX	MEAN GLENOID HEIGHT (mm)	P-VALUE
MALE	36.58±2.61	P<0.001
FEMALE	33.50±2.66	

TABLE 4 GLENOID HEIGHT MEASUREMENTS IN MALES AND FEMALES

SIDE	MALE	FEMALE	P-VALUE
RIGHT	36.80±2.65	33.22±2.33	p<0.001
LEFT	36.35±2.57	33.73±2.96	

4.3 Measurements of the glenoid angles

4.2.3 Glenoid inclination and version

The average inclination angle (Table 5) measured from Orientated and fixed specimens was 6.0°interquartile range 6° to 7°. The average anteversion /retroversion angle (Fig 2) from male and female dry bones was -1.0°±4.0° (-3°-6°) with significant differences $p<0.002$ for glenoid inclination and $p< 0.001$ for glenoid retroversion and $p< 0.01$ for anteversion (Table 6).

For measurements taken there were no significant inter-observer errors found.

TABLE 5 COMPARISON OF GLENOID INCLINATION IN MALES AND FEMALES

SEX	MEAN GLENOID INCLINATION	P-VALUE
MALE	6.44°±1.2	P<0.002
FEMALE	5.56°±1.5	

TABLE 6 COMPARISON OF GLENOID VERSION IN MALES AND FEMALES

SEX	MEAN GLENOID VERSION	P-VALUE
MALE	-3.5°	P<0.001
FEMALE	-3.0	

TABLE 7 COMPARISON OF ALL MEASUREMENTS ON THE RIGHT AND LEFT SIDES

	RIGHT	**LEFT**	**P-VALUE**
GLENOID HEIGHT (mm)	36.17±2.92	35.75±2.86	0.41
GLENOID WIDTH (mm)	24.23±2.26	23.7±2.25	0.17
GLENOID INCLINATION (°)	6.25±1.32	6.27±1.38	0.9
GLENOID VERSION (°)	-3.5±4.5	-3.0±4.0	0.01

There was no significant difference in mean measurements between right and left sides

5 STUDY LIMITATIONS

The study involved analysis of dry human scapulae from the osteology collection from the National Museums of Kenya.

- It was difficult to determine the accurate age of the individual the bones belonged to. However, the status of the epiphysis was documented to distinguish skeletally mature and the immature.
- Some of the scapulae were lost during the retrieval from archaeological sites.

6 DISCUSSION

There have been a few cadaveric studies on the native morphology of the glenoid articular surface of the scapula bone. Amongst these studies various methods of measurements have been used including radiological analysis: plain radiography and CT guided measurements. Direct measurements of fresh or embalmed cadavers as well as measurements of dry bones have denoted significant differences in the glenoid parameters in the African population(31,35).

This present study aims to understand the glenoid morphology in the Kenyan population with an aim to understand any similarities or differences with other populations.

Glenoid width

The mean glenoid width in males was 24.52mm±2.0 and in females 21.80mm±1.91 with significant differences ($p<0.001$).

In males the glenoid width on the right 24.74±2.02mm and the left 24.29±1.98mm while in females right 21.89±1.85mm and the left 21.73±2.01mm $p<0.001$) with males having a significantly wider glenoid cavity compared to the males.

In both sexes right 24.23±2.26mm and the left 23.7±2.25 which was not statistically different in both sexes ($p<0.17$)

In comparison with Mathews. S et al who measured a mean glenoid width in Males30.3mm±3.3 and Females:26.2mm±1.6 who showed a significantly wider glenoid cavity in both sexes in the Swiss population in Europe compared to our population.(4).

TABLE 8 COMPARISON OF GLENOID HEIGHT WITH PREVIOUS STUDIES

Study	**Study type & population**	**Glenoid width (mm)**
Present study	Dry bone (Kenyan)	18.02-30.5mm (23.97±2.26)
Matthews's et al(4)	Cadaveric (swiss)	23.5-34.7mm (27.8mm±3.1)
Distephano et al(54)	Cadaveric	31±2.5mmmm
Churchill et al (31)	Cadaveric	24.3-32.5mm (27.8 mm) males 19.7-26.3 mm (23.6 mm) in females

Glenoid height

In this present study, the mean glenoid height 36.58mm±2.61 while in females was 33.50mm±2.66.In males the glenoid height on the right 36.80±2.65mm and left 36.35±2.57mm and in females glenoid height on the right33.22mm±2.33 and left 33.73mm±2,96 with significant differences between both sides and in both sexes($p<0.001$).The mean measurements on the right side 36.17±2.92mm and the left 35.75±2.86mm in both sexes however this was not statistically significant ($p<0.41$).

This present study affirms the presence of sex differences as described from various studies(55). The mean glenoid height in this present study in both sexes was 35.96±2.88mm compared to the Swiss population in Europe by Mathews. S et al recorded a mean height 36.6±3.6mm (4) while Iannotti et al reported a mean height of 39±3.5mm (32). Our data on glenoid larger was smaller than the glenoid height in the USA recorded 45.7mm (56).

The males were noted to have a significantly larger glenoid than the females in the Kenyan population.

TABLE 9 COMPARISON OF GLENOID HEIGHT WITH PREVIOUS STUDIES

Study	**Study type & population**	**Glenoid height (mm)**
Present study	Dry bone (Kenyan)	28.43-43.23mm (35.96±2.88)
Matthews's et al(4)	Cadaveric (swiss)	31-43.6mm (36.6)
Distephano et al(54)	Cadaveric (unknown)	39.5±2.6mm
Churchill et al(31)	Cadaveric (unknown)	30.4-42.6 mm (37.5) for men 29.4-37 (32.6 mm) for women

Glenoid angles

Glenoid inclination range 6° to 7° and 6.0°interquartile the average anteversion /retroversion angle (Fig 2) from male and female dry bones was anteversion3°- retroversion6° (1.0°±4.0) with significant difference and $p < 0.001$ for glenoid retroversion. In males 6.44° and females 5.56° with a significant sex dimorphism ($p<0.002$). The glenoid version in our population was mainly retroverted.

This is comparison to Swiss population in Europe as recorded by Mathews et al mean glenoid inclination 5.0°±3° with version angles males -3.5° (-13.5°-3.5°) and females -4.0° (-10.5°-3.5°).

In male specimens, the glenoid was inclined superiorly. Churchill et al noted significant differences with an inclination of 7°-15.8° (4°) in males and 1.5°-15.3° (4.5°) in females. White patients had a slightly greater glenoid inclinations mean 4.6°inclination compared to black patients mean, 3.9°superior inclination.

Churchill et al reported a mean glenoid version 9.5° anteversion-10.5°retroversion (retroversion of 1.2°). the male glenoid were more retroverted compared to the women while those of white patients were significantly more retroverted than those from black (mean, 2.7

TABLE 10 COMPARISON OF GLENOID ANGLES WITH PREVIOUS STUDIES

Study	**Study type & population**	**Glenoid inclination**	**Glenoid version**
Present study	Dry bone (Kenyan)	6-7° (6°)	3°anteversion-6°retroversion (-1°±4)
Matthews's et al(4)	cadaveric & radiological (swiss)	0.5° - 13.5° (5.0° ± 3.0°) -3.0°-26° (13.0° ± 7.0) as measured on CT	anteversion13.5 - 3.5(3.5 ± 4.0°) anterversion10.0° - retroversion 10.0° (−1.0° ± 4.0°) as measured on CT
Churchill et al(31)	Cadaveric (unknown)	No data	9.5° anteversion-10.5°retroversion mean retroversion of 1.2°
Manisha et al(57)	Dry bone & radiological	No data	2°anteversion-13°retroversion)6°

7.CONCLUSION

Current advances in total shoulder arthroplasty and reverse shoulder arthroplasty have greatly improved the appreciation of varied anatomy in glenoid anatomy especially in severely arthritic patients.

This present study depicts the normal anatomy of the glenoid morphometry in the Kenyan population. It is crucial for the orthopedic surgeon to plan adequately for the proper glenoid component sizes during shoulder arthroplasty. This will ensure long term improvement of patients' outcomes.

The glenoid size in our population is significantly smaller compared to other populations. The glenoid height and glenoid width were significantly smaller compared to studies done in Europe and the United States. The glenoid width and the height are crucial in estimating the suitable size of the glenoid components as well as the optimal size of the glenoid baseplates required for glenoid resurfacing.

The glenoid inclination in the Kenyan population was noted to be mean of 6° and the glenoid in our population is mostly retroverted and this serves as a guide in implant positioning of the

Appreciation of both the normal and abnormal anatomy will help the orthopedic surgeon understand the patient pathology, and this will lead to enhanced prosthesis selection, component design and surgical techniques.

8. RECOMMENDATION

1. A follow up radiological study on plain radiographic and CT guided measurements will be required in the Kenyan population to correlate measurements taken on dry scapulae bones as this will also serve as a guide during preoperative planning for patients.
2. Preoperative CT guided measurements of the glenoid inclination and version is recommended for patients undergoing shoulder arthroplasty to ensure proper glenoid component sizing and placement intra operatively.

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10. APPENDICES

10.1 data collection sheet

Specimen number:

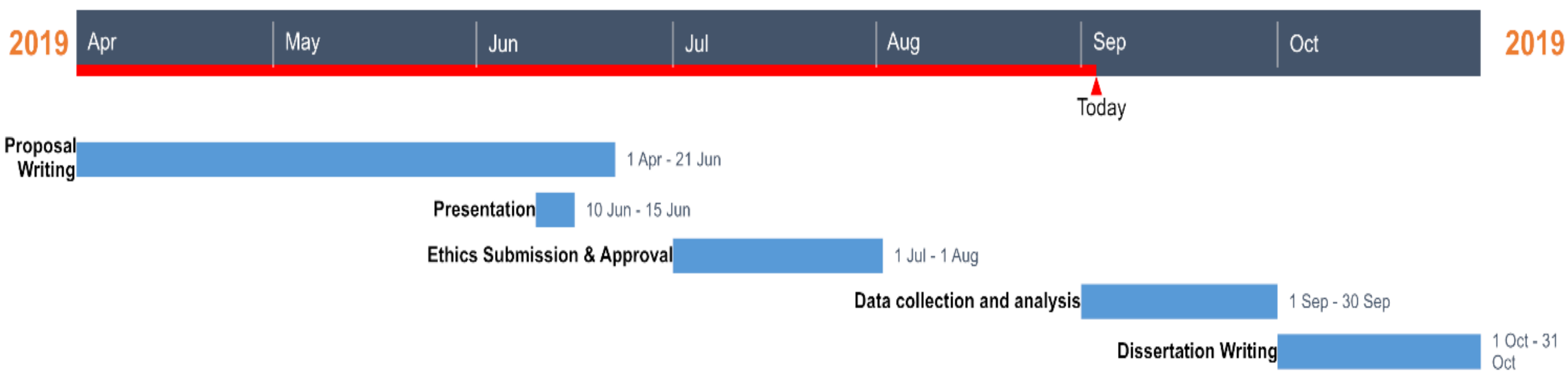
Sex:

Side of the bone:

	Measurement 1	Measurement 2	Average measurement
Glenoid height			
Glenoid width			
Glenoid shape			
Glenoid inclination			
Glenoid version			

10.2 TIMELINE OF THE STUDY:

Proposal writing, presentation and submission for ethical approval will be done April 2019-August 2019 thereafter Data collection and analysis in August 2019 –September 2019 and finally Dissertation writing in September-October 2019.


2019
Apr
May
Jun
Jul
Aug
Sep
Oct
2019
Today
Proposal Writing
1 Apr - 21 Jun
Presentation
10 Jun - 15 Jun
Ethics Submission & Approval
1 Jul - 1 Aug
Data collection and analysis
1 Sep - 30 Sep
Dissertation Writing
1 Oct - 31 Oct

10.3 BUDGET

ITEM	COST (KSHS.)
Research fees (KNH/ERC)	2,000/=
Stationery, printing, and binding	3000/=
Laboratory charges	80000
Specimen processing fee	
Laboratory technician	10000
Museum fees	20000
Contingencies	5,000/=
Statistician	35,000/=
Total	**150,500/=**