MORPHOMETRIC COMPARISON OF KENYAN ADULT MANDIBLES WITH RECONSTRUCTION PLATE PARAMETERS.

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A dissertation submitted in part fulfillment for the award of the degree of Master of Dental Surgery in Oral and Maxillofacial Surgery of the University of Nairobi

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DECLARATION

I hereby declare that this dissertation is my original work and has not been submitted in any other university.

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Sign:_____ Date: 25th September 2008

This thesis has been submitted to the university with our approval as supervisors.

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DEDICATION

This dissertation is dedicated to my mother, sister and brothers for their tremendous amount of moral support during the period of my postgraduate training.

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I would like to acknowledge my supervisors Professor Chindia, Professor Hassanali and Professor Pokhariyal for their constant guidance and advise on the project.

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ABSTRACT

Objective: To determine the archival morphometry of the mandible of Kenyan male and female adults and to relate them to available mandibular reconstruction plates.

Study design: A descriptive cross-sectional study using quantitative techniques.

Material and Methods: Intact adult mandibles were obtained from the National Museums of Kenya, Nairobi and from the Department of Human Anatomy, University of Nairobi. Standardized selective measurements including curvilinear measurement of the body and linear measurement of the height of the ramus of the mandible and thickness of the ramus and body at the lower border of the mandible, were taken on 82 mandibles (n=48 for males and n=34 for females) and recorded on a special data collection chart. The morphometry of the mandible was then analysed statistically for differences between the male and female, for the left and right sides of the mandible and; with the sizes of the available mandibular reconstruction plates of the 2.7 mm type manufactured by SYNTHES^{R} with a level of significance of $p<0.05$ having been set. Pearson's correlation coefficients were computed for the variables to determine the nature and strength of the relationship between them.

Results: The average length of the mandible in males for the right and left sides was 98.6 mm and 100.5 mm respectively while for the females this was 92.2 mm and 94.5 mm respectively. The average height of the ramus of the mandible in males for the right and left sides was 57.40 mm and 58.07 mm respectively while for females this was 51.81 and 52.20 respectively. Significant differences were noted among the curved lengths and heights of the mandible between males and females ($p<0.05$) with a strong positive correlation ($r=$ 0.902 and 0.825). In addition significant differences between the right and left sides of the mandible were noted ($p<0.05$) with a strong positive correlation ($r=$ 0.964). Significant differences were noted between the length of the mandible and the lengths of the reconstruction plates ($p<0.05$) with a weak positive correlation for the straight plate ($r=$ 0.284), a weak negative correlation for the angled plate ($r=$ -0.327) and a weak negative correlation for the plate with condylar head ($r=$ -0.156).

There were no significant differences in the thicknesses of the mandible between males and females and; between the left and right sides of the mandible with averages of 13.94 mm at the symphysis, 11.00 mm at the canine, 10.33 at the mental foramen, 11.06 at the bifurcation of the 1st molar, 12.36 mm at the bifurcation of the 2nd molar, 8.62 mm at the level of the anterior ramus, 5.47 mm at gonion and 5.89 mm at the midpoint of the ramus, ($p>0.05$) with strong positive correlations. Significant differences were, however, noted between the thicknesses of the body and ramus of the mandible and the sizes of the screws ($p<0.05$) with weak negative correlations.

Conclusions: There were significant differences between the sizes of Kenyan mandibles and the available reconstruction plates. There were significant differences between male and female mandibles in relation to curvilinear dimensions but not in the thickness with strong positive correlations. There was also a significant difference between the right and left sides of the mandible with strong positive correlations. There were significant differences between the sizes of the mandibles and the plates with weak correlations.

Recommendations: The average linear dimensions and thickness obtained from a sample of Kenyan mandibles can be used in the selection of appropriate plates or their modification during surgical reconstructive procedures. A further study to compare the direct measurements obtained in this study with measurements of mandibles obtained from standadized panoramic radiographs could be done to assess their accuracy and enable extrapolation of actual sizes of mandibles from the radiographs. Where available, 3-D CT-scan should be used to take accurate measurements of the mandible before reconstruction.

CHAPTER 1

1. INTRODUCTION AND LITERATURE REVIEW

1.1 Anatomy of the mandible

The mandible forms the lower part of the facial skeleton, which together with the calvarium collectively form the skull. It consists of a horizontal U-shaped body which is continuous at its posterior end with a pair of vertical rami. The body of the mandible extends upwards as the alveolar process which supports the teeth. On the outer surface of the body, the sharp anterior border of the ramus extends forward as the external oblique line to which the buccinator muscle is attached. The mental foramen lies halfway between the upper and lower borders of the body in line with the interval between the two premolars. The inner surface of the body is characterized by the mylohyoid ridge which runs downwards and forwards and is the site of attachment for the mylohyoid muscle.The mental spines or genial tubercles are found in the midline of the inner surface where the genioglossus and geniohyoid muscles are attached.[1,2]

Most of the lateral surface of the ramus gives insertion of the masseter muscle. The posterior border of the ramus is projected up as the head and neck of the condyle. The anterior border continues up as the coronoid process to which the temporalis muscle is attached. The medial surface of the ramus is characterised by the lingula, which is found anterior to the mandibular foramen in which pass the inferior alveolar nerve and vessels. The medial pterigoid muscle is attached to the lower medial aspect of the ramus.[1,2] The head of the condyle of the mandible articulates with the mandibular (glenoid) fossa of the temporal bone at the base of the skull to form the temporo-mandibular joint or cranio-mandibular articulation.[2] The inferior and posterior borders form an angle at the lower posterior end of the mandible. A comprehensive illustration of the anatomy of the mandible is shown in Fig. 1.

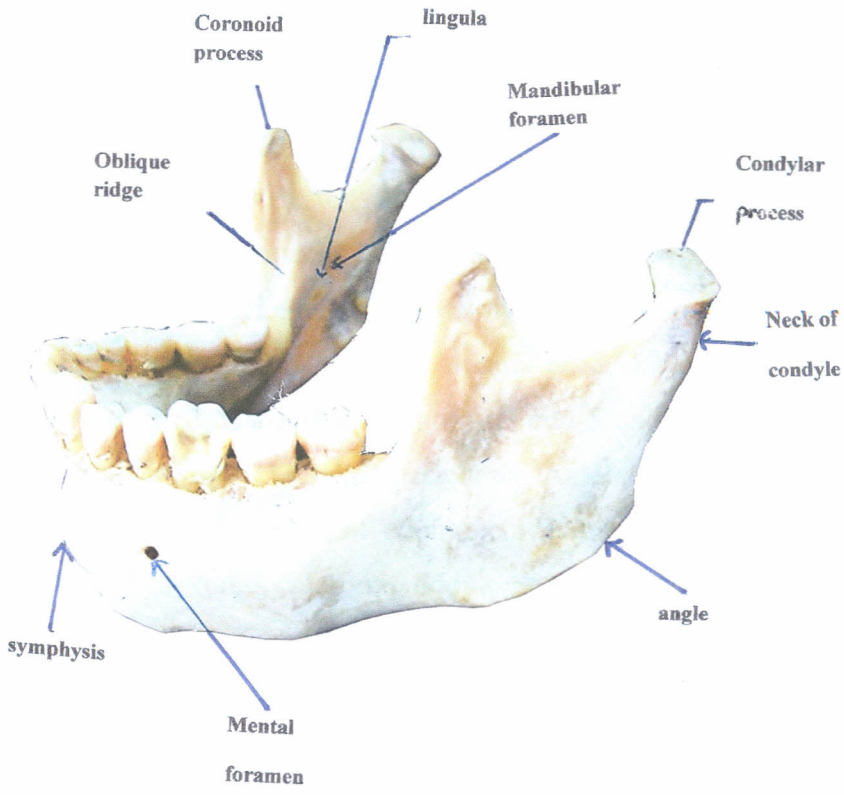

Fig. 1. A labeled view of the mandible.

1.2 *Destructive diseases and conditions of the jaws*

The mandible may be involved in pathology leading to a breach in its continuity requiring reconstruction after the disease is resected. The most common indications for mandibular reconstruction include surgical resection for tumours involving the mandible, oral cavity and oropharynx; trauma, infections and osteoradionecrosis.[3] Some of the neoplastic processes include odontogenic tumours which have been classified according to the World Health Organization (WHO) into groups 1,2 and 3.[4,5] Among the group 1 tumours, ameloblastoma is the commonest and also includes others like ameloblastic fibroma, odontogenic fibroma, odontogenic myxoma and benign cementoblastoma. Group 2 tumours include malignant odontogenic tumours like odontogenic carcinoma and

malignant ameloblastoma. Group 3 tumours are classified as neoplasms and other lesions related to bone and they include cemento-ossifying fibroma. This category includes non-neoplastic bone lesions like fibrous dysplasia of the jaws, cementosseous dysplasias, cherubism, central giant cell granuloma, aneurysmal bone cyst, solitary bone tumours and the melanotic neuroectodermal tumour of infancy.

Literature shows destructive jaw lesions to be common in Africa. Simon et al.[6] have studied the occurrence of odontogenic tumours in Tanzania over a 15-year period and found that ameloblastoma was the most commonly seen odontogenic tumour at 73.7% followed by odontogenic myxoma at 10.3%. Akinola et al.[7] have reviewed 319 cases of odontoegnic tumours at a Nigerian teaching hospital and found 308 of the cases (96.6%) having been intraosseous while 11 (3.4%) peripheral. Ameloblastoma with a predilection for the mandible was the most frequent odontogenic tumour followed by adenomatoid odontogenic tumour and myxoma, calcifying odontogenic cyst and odontogenic fibroma. In Kenya, case records from the Kenyatta National Hospital showing the characteristics of ameloblastoma,mainly in the mandible, accounted for 78.2% of all the tumours. The treatment offered was mainly radical excision in line with the current concepts of the biology of the disease and where resources were available and operation feasible, jaw reconstruction was carried out to restore aesthetics and function.[8]

Radiotherapy for head and neck cancers may have severe late effects with osteoradionecrosis of the mandible being the most major complication among the sequelae. It is best treated by mandibular resection and microvascular free bone flaps.[9,10] Odhiambo et al.[11] analysed the pattern of firearm injuries seen in patients, over a two-year period, and showed significant involvement of the mandible in gunshot injuries requiring reconstruction.

An example of a destructive jaw condition requiring reconstruction is shown in Figs.2 and 3. Treatment of these destructive conditions invariably requires mandibular reconstruction at some stage in their management (as shown in Figs. 4 and 5), to restore function. mastication, deglutition, airway and structural support for the tongue and larynx.[12]

Fig.2. A patient with a massive mandibular tumour.

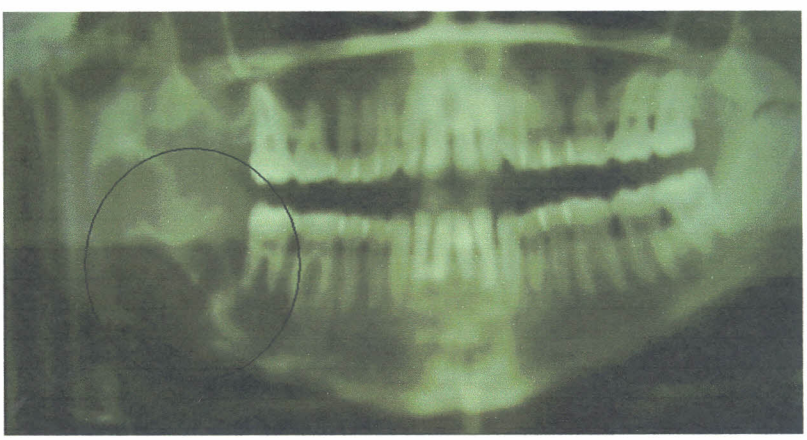

Fig.3.An orthopantomogram depicting a mandibular destructive tumour (circled).

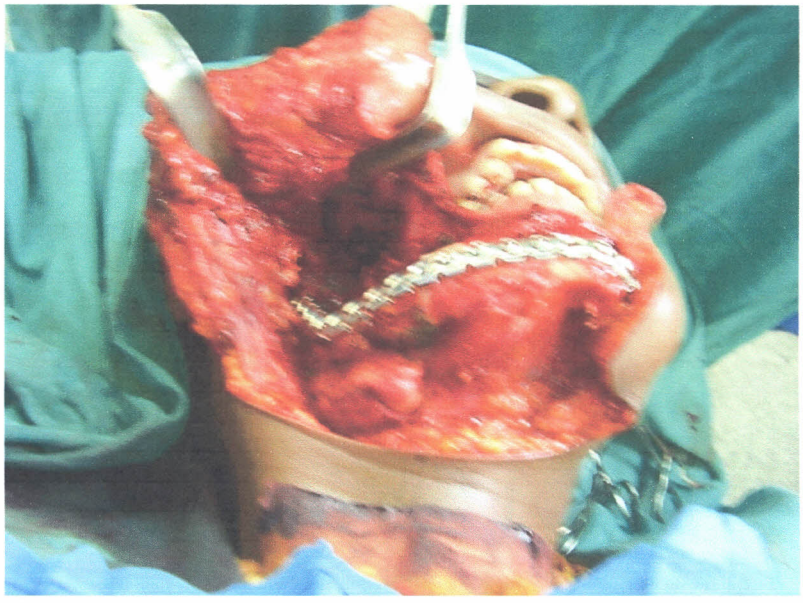

Fig.4. A clinical depiction of a plate in situ after surgical resection of a mandibular tumour.

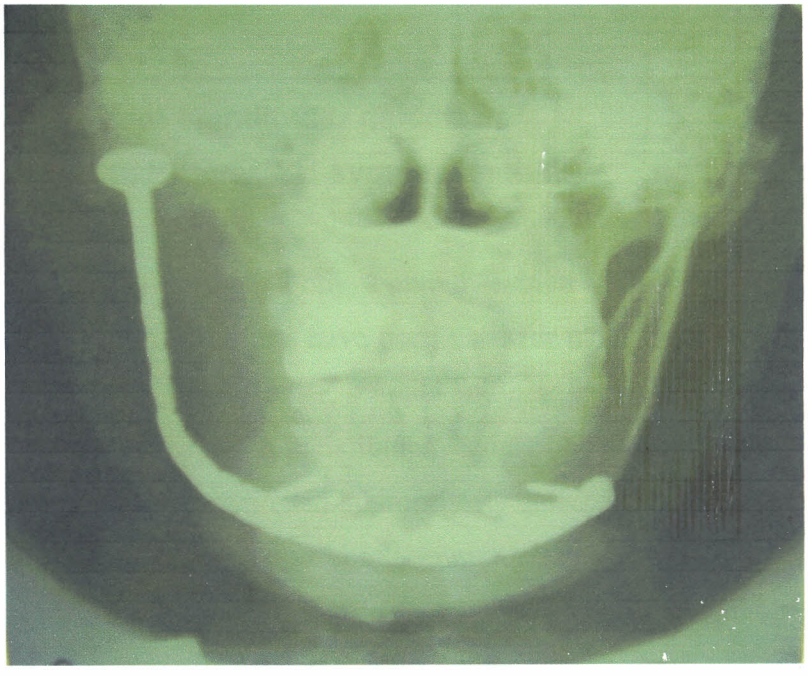

Fig.5. A radiographic depiction of a reconstruction plate with a condylar head in situ following mandibular tumour resection.

1.3 Morphometry of the mandible, plate design and reconstruction dimensions

In mandibular reconstruction, it is important to have an accurate classification and quantification of the defect and an understanding of the likely functional deficits. Urken et al.[12] describe a classification scheme for bony mandibular as well as a scheme to classify soft tissue defects that are often encountered with the mandibular patyhology (Fig. 6).

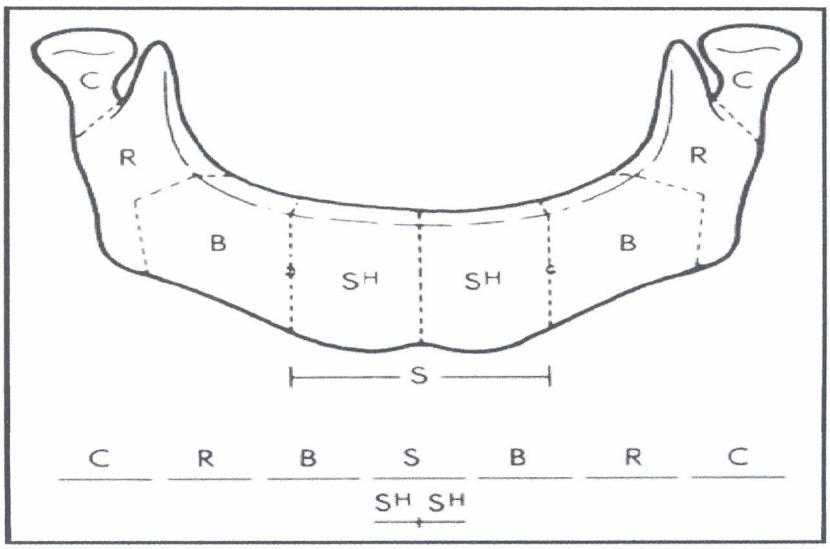

Fig.6. **Urken classification of mandibular defects: C-condyle, R-ramus, B-body, SH-symphysis (half)**

The ideal reconstruction restores the bony contour which would involve metric measurements. Historically free bone grafts have been used for mandibular reconstruction obtained from the calvarium, rib, tibia, fibular, scapula and iliac crest. Use of vascularized bone grafts has become state of the art in mandibular reconstruction,[12,13] while alloplastic reconstruction plates also remain an option in appropriately selected patients according to Koch et al.[14] It has been found that the proposal of Sammon et al.[30] of constructing a plate using each patient's mandibular measurements has met with technical difficulties as per reviews by Mehta and Descher[15] and Goh et al.[31]Mandibular bone plates and screws are made of stainless steel, vitallium and titanium.[15] A sample of commonly used plates and screws with their dimensions are shown in Figs.7 and 8.[16]

(a) Straight mandibular reconstruction plate

No.of holes	5	6	8	10	12	14	16	18	20	22	24
Length of plate (mm)	40	48	64	80	96	112	128	144	160	176	192

(b) Angled mandibular reconstruction plate

No.of holes	4+16	5+17	6+18
Length of plate (mm)	32+128	40+136	48+144

(c) Reconstruction plate with condylar head.

Holes	16+3	18+4	20+5
Length (mm)	128+50	144+55	160+60

*Fig.7. Shows reconstructive plates of various types (thickness of 3.1mm).

(a) Full mandibular reconstruction plate

Holes	26	28	32
Dimensions (total length in mm)	Small (208)	Medium (224)	Large (256)

(b) A representative mandibular cortical screw

Total length sizes (mm): 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40

*Fig.8. Depicts a full mandibular reconstruction plate and screw.

*Sample figures used with permission from agent (Amiken Ltd).

Microvascular reconstruction with osseous free tissue transfer also requires rigid internal fixation with plates and screws at osteotomy sites.[15] These procedures will require metric quantification of the defects. Arias et al.[17] reviewed the results of mandibular reconstruction plating over a 5-year period and recommended the use of new plating designs. Dimitroulis[18] has shown that variables likely to influence the outcome of mandibular reconstruction were the site and extent of the defect, the needs and tolerance of the patient, the timing of reconstruction and the surgical skill and techniques available. Mutave et al.[19] determined the range of ablative surgery and rehabilitative procedures performed on maxillofacial structures and found the rehabilitative procedures to have been largely inadequate.

Population group variations in mandibular and dental arch anatomic parameters have been shown in several studies.[20,21,22,23,24] Didia and Dapper[20] found that the mean values of the mandibular angle, mandibular length and mandibular ramus height in Eastern Nigerians compared favourably with those of other negroid populations and was smaller than the Caucasians. De Sousa et al.[25] analysed the correlation of the gonial angle with condylar measurements on dry mandibles and found a statistically significant positive correlation. Laster et al.[26] compared actual bony measurements on the mandible with radiographic measurements showing that panoramic radiographs should be used with caution when making absolute measurements or relative comparisons. The accuracy of linear measurements in the jaw bones obtained using magnetic resonance imaging is comparable to that of dental computerized tomography and is not significantly different from direct osteometry.[27] Hanazawa et al.[29] showed that multiplaner computerised tomography (CT) allows for more accurate measurements of the mandible than by conventional C.T.
The study by Takahashi and Pan[28] on mandibular measurements in the macaque monkey showed significant differences in the morphometry, mechanics between male and female.

Simulation model for dental arch shapes have shown parabolic to elliptical shapes and that this could be used to show population differences.[22] The study of Mbajiorgu et al.[21] of mandibular lengths, heights and mandibular angles of black Zimbabweans could be a useful anthropological tool in population group identity. Catic et al.[32] evaluated the precision of dimensional measurements of the dry mandible and orthopantomographic images and their reliability. The measurements on one side of the image of the mandible were very close to the actual dimensions on the dry mandibles whereas measurements that extended across the midline of the mandible were greatly enlarged. Turp et al.[33] determined the asymmetry of condylar and rami heights from orthopantomograms and compared results with true values obtained by direct measurements of the skulls and found a statistically significant positive correlation. The degree of bony asymmetry between the right and left mandibular condyles and rami has been shown as part of the biologic variations of humans.[34]

Morphometric measurements on human cadaver mandibles including the ramus height and

width, the angle between the ramus and body and the relationship between the mental foramen and teeth was conducted to obtain standards so as to relate them to reconstructive surgical areas.[35] Larheim and Svanaes[36] assessed the linear dimensions and angles, from panoramic radiographs and found acceptable reproducibility for vertical and angular mandibular variables and unreliable for horizontal variables. The study by Puisoru et al.[24] showed variability in dry human mandibles from different geographical regions. The mandibular angle in the African, was lower than that in Asians, and there were significant differences in the mandibular length. Thus the morphometry of the mandible in the African shows differences from that of Caucasians although the methodology in the various studies need to be harmonized.

There is limited data on the morphometry of the Kenyan mandible. However, these parameters could be applicable for undertaking surgery using reconstruction plates of specific sizes manufactured outside Kenya. Previous studies have not related mandibular morphometry to sizes of reconstruction plates. This study determined the morphometric requirements of mandibular reconstruction plates suited for a Kenyan population.

1.4 STATEMENT OF THE PROBLEM AND JUSTIFICATION.

Mandibular destructive diseases and conditions which may require ablative treatment and reconstruction are common. Information is limited on Kenyan mandibular morphology in relation to mandibular reconstruction plates. Baseline data will be available on morphometry of the mandible in selected Kenyan populations. Presently, whenever mandibular reconstruction is indicated, selection of reconstruction plates is usually done on estimations based on radiographs which are not standardized. The data will allow for better preoperative planning in terms of selection of the available reconstruction plates.

1.5 HYPOTHESIS:

There is a significant difference between the mandibles of Kenyan African adults and available reconstruction plates.

1.6 BROAD OBJECTIVE: To determine the mandibular morphometry of Kenyan African adult male and female mandibles with respect to reconstruction plates.

1.7 SPECIFIC OBJECTIVES :

1. To determine the morphometric dimensions of mandibles of Kenyan male and female adults.
2. To determine the thickness of the mandible at selected sites.
3. To compare male and female and between the right and left sides of the mandible.
4. To relate the morphometric dimensions of the mandible with those of the reconstruction plates.

CHAPTER 2

2. MATERIAL AND METHODS

2.1 Study area

Intact adult mandibles were obtained from the National Museums of Kenya, Nairobi which has animal, human and other scientific collections. The human osteological collection is from Central Province of Kenya (mainly Kikuyu of bantu origin) of persons who died during the Mau Mau period in the 1950's as well as those recorded as having been collected in the early 1970's.[37] Intact human mandibles were also obtained from the Department of Human Anatomy, School of Medicine, University of Nairobi.[38] These were mainly from the Maasai community (Nilo-hamitic) whose cadavers are available for dissection under the Human Anatomy Act Cap 252 of the laws of Kenya.[39]

2.2 Study Design

This was a descriptive cross-sectional study using quantitative techniques of data collection. Selective curvilinear and thickness measurements of the mandible were taken in order to determine the morphometric profile of the mandible. Tests of significance and correlation were done for measurements of the mandible between males and females, the right and left sides of the mandible and for reconstruction plates.

2.2.1 Sample size

The formula $n = \frac{S_1^2 + S_2^2}{e^2}$

used for comparing 2 population means, was used for sample size determination.[40]

Where n = the sample size.

S_1= the standard deviation for male mandibles and S_2 is standard deviation for female mandibles.

e = the difference between the two standard deviations.

A study by Puisoru et al.[24] to analyse mandibular variability in humans of different geographic areas gave a standard deviation of 1.11 for males and 0.89 for females for *values of condylar height measurement.*

$$\frac{1.11^2 + 0.89^2}{0.22^2} = 41.65$$

A sample size of 42 each for male and female mandibles was to be obtained constituting 84 mandibles required for the study.

2.2.2 Sampling Method

Due to limitations of availability of whole mandibles, they were from the convenient study sites, including all the available mandibles meeting the inclusion criteria.

2.2.3 Inclusion Criteria

Intact adult mandibles with 3rd molars erupted (mean age 18years), identified as male or female were included for the study.

2.2.4 Exclusion Criteria

- Mandibles that were broken or incomplete.
- Mandibles whose 3rd molars were not present.
- Mandibles whose gender was not identified.
- Edentulous mandibles.

2.2.5 Data collection instruments.

A digital Vernier calipers[23,41] seen in Fig.9 was used to take the straight measurements to the nearest second decimal place while a calibrated flexitape[23] as seen in Fig.10 was used to take the curved length of the mandible as described in section 2.2.6 on the variables.

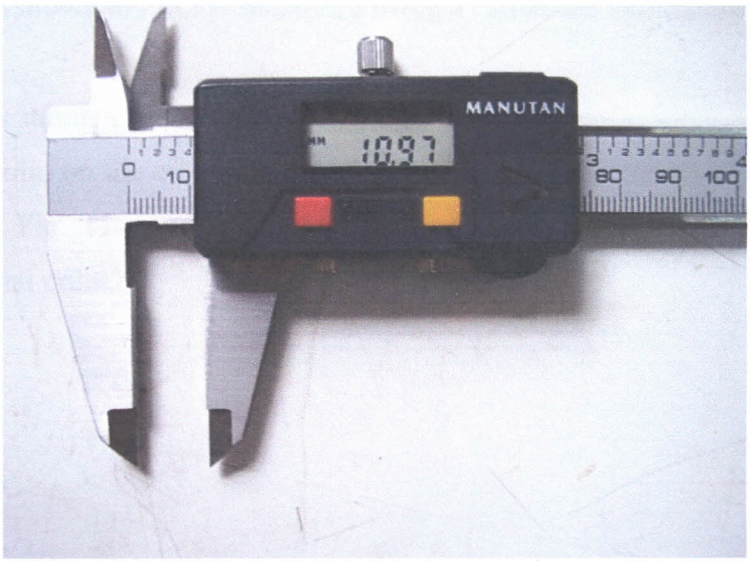

Fig.9. Showing the digital Vernier calipers used to take straight measurements

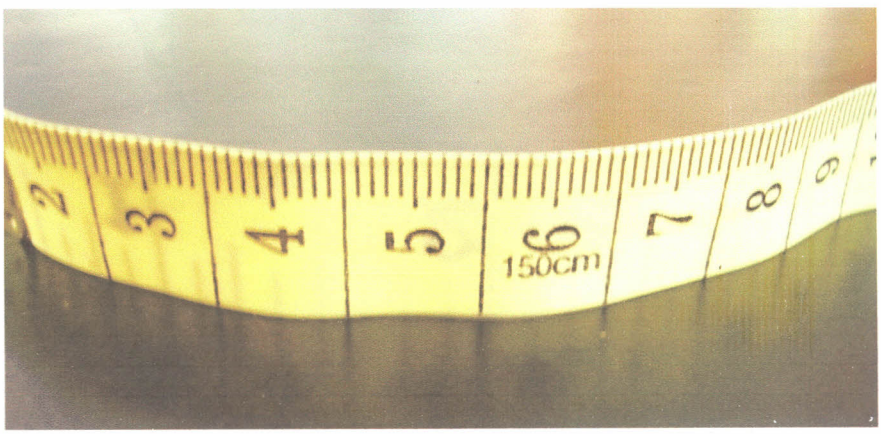

Fig.10. Showing the calibrated flexitape used to take the curved length of the mandible.

2.2.6 Variables

2.2.6(a) *Dependent variables*

1. Curvilinear length of the mandible -Right and left- taken from the most anterior point on the symphysis of the mandible (pogonion) to the angle of the mandible (gonion) – as shown in Fig.11- measured using a calibrated flexitape taken in mm.

2. Height of the ramus of the mandible (straight measurement)- Right and left– from the highest point on the condyle (condylion) to the angle of the mandible (gonion)- as shown in Fig. 11-measured using the Vernier calipers in mm to the nearest second decimal point.

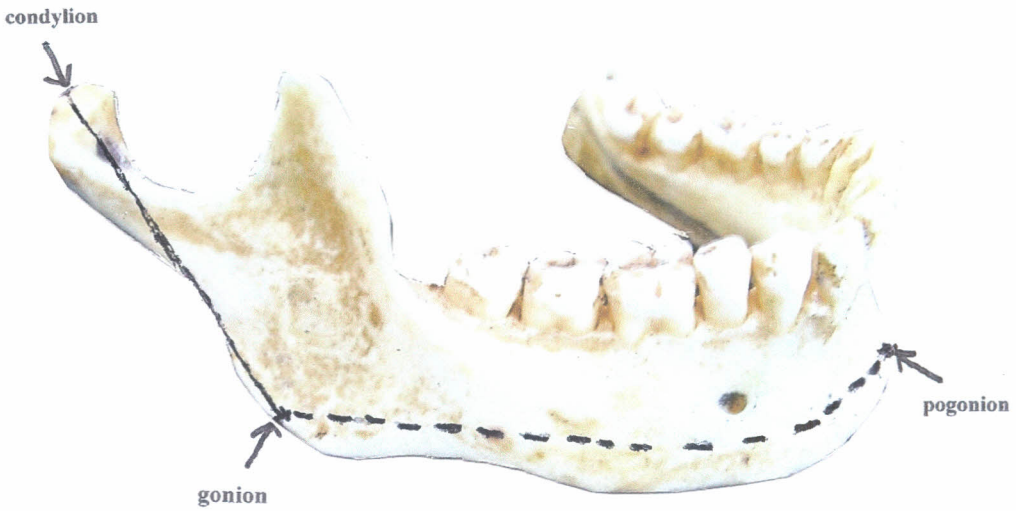

Fig.11. Showing the curvilinear length (gonion-pogonion) and height (condylion-gonion) of the mandible.

3. Thickness of the body of the mandible (taken 1cm above the lower border of the mandible)- as shown in Fig.12.

(i) at the symphysis menti (Right and left).

(ii) at the level of the canine (Right and left).

(iii) at the level of the mental foramen (Right and left).

(iv) at the level of the bifurcation of the first molar (Right and left).

(v) at the level of the bifurcation of the second permanent molar (Right and left).

(vi) at the level of a perpendicular dropped from the anterior border of the ramus of the mandible (Right and left).

4. Thickness of the ramus of the mandible (taken 1cm from the posterior border of the ramus of the mandible)- as shown in Fig.12.

(i) at the midpoint of the ramus (Right and left)

(ii) at the level between the midpoint of the ramus and condylion (Right and left).

(iii) at the level between the midpoint of the ramus and gonion (Right and left).

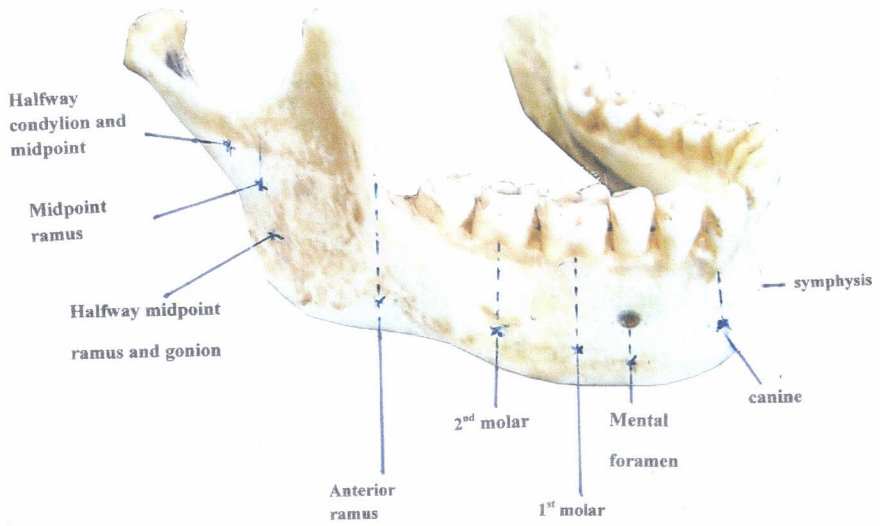

Fig.12. Landmarks for the thickness of the mandible.

4. Height from the lower border of the mandible to the inferior part of the mental foramen (Right and left).

- Male and female gender.
- Right and left sides of the mandible.

Plates for mandibular reconstruction which were used for comparison with the sizes of the mandible were obtained from a catalogue by SYNTHES^{R} as shown in Figs.7 and 8.[16]

2.2.7 Minimizing errors and biases

The calibration of the measurements was done under supervision on the use of the Vernier calipers and flexitape, as well as the stable anatomical landmarks on the mandible and their reproducibility. To assess intra-observer variability, every 10th mandible was measured twice. A repeat measurement to check for inter-observer variability was done by a graduate with a Bachelor of Science in Anatomy, and was found to be within 5% of the margin of error.

2.2.8 Data recording

Data were recorded on specially designed data chart (Appendix 1).

2.2.9 Data analysis and presentation

Data were analysed using the computer software SPSS version 12.0. Descriptive statistics included measures of central tendency (mean) and measures of dispersion (standard deviation). Statistical tests were done to determine whether there was a significant difference between the male and female mandibles, right and left sides of the mandible as well as population group variation (t-test). Significant difference between the sizes of the reconstruction plates and the sizes of the mandibles were also determined. The significance level was set at $p< 0.05$. Correlation coefficients were computed for male and female mandibles, right and left sides of the mandible and for the available reconstruction plate dimensions. The data obtained were also compared with those obtained from previous similar studies on the mandible from different population groups.

2.3 Data limitations:-

(i) Exact ages of the mandibles were not ascertained.

(ii) Due consideration should be taken when generalizing the data for a Kenyan population as the mandibles obtained were from particular communities.

(iii) Due to an inadequate number of female mandibles, only 34 were obtained for the study. However, the central limit theorem[42,43] which underlies a normal distribution was invoked. With sample sizes greater than 30 ($n>30$), the sampling distribution becomes more and more like a normal distribution and can be used for statistical inference.

2.4 ETHICAL CONSIDERATIONS

Approval was obtained from the Ethics, Research and Standards Committee of the Kenyatta National Hospital, Approval No. P77/4/2007 (Appendix 2). Permission was obtained from the Director, National Museums of Kenya and from the University of Nairobi's Department of Human Anatomy to use the materials. Permission was also sought for the use of the images and sizes of the reconstruction plates manufactured by SYNTHES through the local agent.

CHAPTER 3

RESULTS

Among the 82 mandibles measured, 48 were male, 34 were female. The mean value of the length of the right mandible in males was 98.6 mm while that of the left was 100.5 mm. The mean length of the right and left mandibles in females was 92.2 mm and 94.5 mm respectively as shown in Table 1. Independent t-test done for the body length in males and females showed there was a significant difference in the body lengths between males and females ($t=7.013$; $p<0.05$) with a strong positive correlation of 0.902. Furthermore, there were statistically significant differences between the right and left sides of the mandible ($p<0.05$) with a strong positive correlation of 0.964 .

Table 1. The length of the body of the mandible according to gender.

		Length of the mandible (mm)	
		R	L
Male	Maximum	109.0	111.0
(n=48)	Minimum	90.0	94.0
	Mean	98.6	100.9
	S.D	4.39	3.99
Female	Maximum	100.0	105.0
(n=34)	Minimum	84.0	83.0
	Mean	92.2	94.5
	S.D	3.63	4.69

Mean length (mm) of the mandible for both genders= 96.5±5.19

$r= 0.902$ $p<0.05$ for males and females

$r=0.964$ $p<0.05$ for right and left sides

The mean height of the right and left mandibles in males was 57.40 and 58.07mm respectively. The mean height of the mandible in females was 51.81 and 52.20mm respectively (Table 2). The t-test done for the height of male and female mandibles showed significant differences between them ($t = 5.399$; $p<0.05$) with a strong correlation of 0.825. There was a significant difference in height between the right and left sides ($p<0.05$) with a strong correlation of 0.887.

Table 2. The height of the ramus of the mandible according to gender.

		Height of the ramus (mm)	
		R	L
Male	Maximum	70.80	69.30
(n=48)	Minimum	45.60	48.90
	Mean	57.40	58.07
	S.D	4.86	7.56
Female	Maximum	62.42	59.70
(n=34)	Minimum	42.40	42.70
	Mean	51.81	52.20
	S.D	4.25	4.28

Mean height (mm) of the mandible for both genders= 54.88±5.27

$r=0.825$ $p<0.05$ for males and females

$r=0.887$ $p<0.05$ for right and left sides

The averages of the length of the straight plate, the length and height of the angled plate and the length and height of the plate with a condylar head were obtained (Table 3) to enable comparison with the average length and height of the mandible. There was significant difference compared with the average lengths of the mandible ($p<0.05$) with a weak positive correlation coefficient of 0.284. The test statistics for the body length of the mandible in males and females were then compared with the test value of the length of the angled plate and the p-values obtained were significant compared with the significance level of 0.05 with weak negative correlations of -0.500 and -0.327 in males and females respectively. The height of the angled plate was significantly different compared to the height of the ramus of the mandible ($p<0.05$) and a very strong negative correlation of -0.934 and -0.781 for males and females respectively. The length of the plate with a condylar head was significantly different compared to the length of the mandible ($p<0.05$) with a correlation of -0.655 and -0.156 respectively for males and females.

Table 3. Maximum, minimum and standard deviation of straight, angled and plate with condylar head plates.

Type of Plate	Straight plate (n=11)	Angled plate (n=3)		Plate with condylar head (n=3)	
	Length (mm)	Length (mm)	Height (mm)	Length (mm)	Height (mm)
Maximum	192	144	48	160	60
Minimum	40	128	32	128	50
Std. Deviation	51.90	8.00	8.00	16.00	5.00

Straight plate $r=0.284$ $p<0.05$. Angled plate against length of male and female mandibles $r=-0.500$ and -0.327 $p<0.05$, against height $r=-0.934$ and -0.781 $p<0.05$. Plate with condylar head $r=-0.655$ and -0.156 respectively $p<0.05$

Combined mean length of male and female against straight plate $r=-0.333$ $p<0.05$, against angled plate $r=-0.455$ $p<0.05$, against plate with condylar head $r=-0.225$

The average total length of the mandible was obtained from the sum total of the left and right body lengths and ramus height (Table 4), for comparison with the full mandibular reconstruction plates. It showed that the mean total length of the mandible in both males and females was greater than that of the available full mandibular reconstruction plates ($p<0.05$) and moderately strong positive correlation of 0.684 and 0.521 in males and females respectively.

Table 4. Total length of the mandible (sum of right and left length and height)

	Maximum (mm)	Minimum (mm)	Mean	Std. Dev
Male (n=48)	343.50	269.00	313.74	15.04
Female (n=34)	322.40	268.90	290.78	13.49

Combined mean for total length (mm) for males and females= 302.26±18.25

Sizes of full mandibular reconstruction plates-

-small= 208mm

-medium= 224mm

-large= 256mm

for males $r= 0.684$, $p<0.05$

for females $r=0.521$, $p<0.05$

for combined average $r=0.574$, $p<0.05$

The thicknesses of the body and the ramus of the mandible were taken at selected points and a second figure derived by adding 3.1mm being the thickness of the plate, as shown in Tables 5-8, in order to enable comparison with the screws used in securing the plates to the mandible. There was no significant difference in the thickness at the symphysis between males and females ($p>0.05$) with a very strong positive correlation of 0.902. There was no significant difference between the right and left sides of the mandibular symphysis thickness ($p>0.05$) with a very strong correlation of 0.964. There was no significant difference in the thickness at the canine between males and females ($p>0.05$) with a strong correlation of 0.826. There was no significant difference between the right and left sides of the mandible ($p>0.05$) with a strong correlation of 0.888. Significant differences were noted between the screws and the thickness at the symphysis and at the canine with plate thickness added ($p<0.05$) with weak correlations of 0.145 and 0.237 respectively.

Table 5. Body thickness at symphysis and canine areas without plate thickness added and with plate thickness added (highlighted).

		Body thickness at symphisis (With plate thickness 3.1mm added)		Body thickness at canine (With plate thickness 3.1mm added)	
		Right	Left	Right	Left
Male (n=48)	Mean	14.49 (17.59)	14.42 (17.52)	11.27 (14.37)	11.29 (14.39)
	S.D	1.56	1.69	1.23	1.28
Female (n=34)	Mean	13.73 (16.83)	13.73 (16.83)	10.62 (13.72)	10.84 (13.94)
	S.D	1.43	1.43	1.23	1.41

Combined mean thickness (mm) of male and female at symphysis=14.12±1.63, at canine= 10.97±1.25.

At symphysis-Male and female $r=0.902$, $p>0.05$. Right and left sides $r=0.964$, $p>0.05$.Screw size $r=0.145$, $p<0.05$.At canine- Male and female $r=0.826$, $p>0.05$. Right and left sides $r=0.888$, $p>0.05$. Screw size $r=0.237$, $p<0.05$.

There was no significant difference in the thickness at the mental foramen and at the bifurcation of the 1st molar between males and females ($p>0.05$) with strong positive correlations of 0.899 and 0 .756 respectively. There was no significant difference between the right and left sides of the mandible at the mental foramen and at the bifurcation of the 1st molar thicknesses ($p>0.05$) with strong positive correlations of 0.961 and 0.818 respectively. Significant differences were noted between the screws and the thickness at the mental foramen and at the bifurcation of the 1st molar with plate thickness added ($p<0.05$) with weak correlations of 0.369 and 0.465 respectively, as shown in Table 6.

Table 6. Thickness at mental foramen and bifurcation of first molar without plate thickness added and with plate thickness added (highlighted).

Sex of the mandible		Thickness at mental foramen (With plate thickness 3.1mm added)		Thickness at bifurcation 1st molar (With plate thickness 3.1mm added)	
		Right	Left	Right	Left
Male	Mean	10.23	10.31	10.87	10.85
(n=48)		(13.33)	(13.41)	(13.97)	(13.95)
	S.D	1.13	1.14	1.32	1.31
Female	Mean	10.46	10.32	11.31	11.21
(n=34)		(13.56)	(13.42)	(14.41)	(14.31)
	S.D	1.27	1.34	1.44	1.41

Combined mean thickness of male and female at mental foramen=10.34±1.22, at 1st molar= 11.03±1.36.

At mental foramen-Male and female $r=0.899$, $p>0.05$. Right and left sides $r=0.961$, $p>0.05$.Screw size $r=0.369$, $p<0.05$.

At bifurcation of 1st molar- Male and female $r=0.756$, $p>0.05$. Right and left sides $r=0.818$, $p>0.05$. Screw size $r=0.465$, $p<0.05$.

As shown in Table 7, there was no significant difference in the thickness at the bifurcation of the 2nd molar and at the anterior ramus level between males and females ($p>0.05$) with correlations of 0.733 and 0.612 respectively. There were significant differences between the right and left sides of the mandible at the bifurcation of the 2nd molar and anterior ramus ($p<0.05$) with correlations of 0.795 and 0.674 respectively. Significant differences were noted between the screws and the thickness at the bifurcation of the 2nd molar and at the anterior ramus with plate thickness added ($p<0.05$) with weak correlations of 0.117 and 0.133 respectively.

Table 7. Thickness at bifurcation of 2nd molar and at the level of anterior ramus without plate thickness added and with plate thickness added (highlighted).

	Thickness at bifurcation 2nd molar (With plate thickness 3.1mm added)		Thickness at anterior ramus (With plate thickness 3.1mm added)	
	Right	Left	Right	Left
Male (n=48)	Mean	11.99	12.29	8.28	8.87
		(15.09)	(15.39)	(11.38)	(11.97)
	S.D	1.39	1.33	1.39	1.63
Female (n=34)	Mean	12.38	12.77	8.42	8.91
		(15.48)	(15.87)	(11.52)	(12.01)
	S.D	1.46	1.43	1.57	1.73

Combined mean thickness of male and female at 2nd molar=12.15±1.39, at anterior ramus= 8.38±1.44.

At bifurcation of 2nd molar-Male and female r=.0733, $p>0.05$. Right and left sides r=0.795, $p<0.05$*.Screw size r=0.117, $p<0.05$*.

At the level of anterior ramus- Male and female r=0.612, $p>0.05$. Right and left sides r=0.674, $p<0.05$*. Screw size r=0.133, $p<0.05$*.

There was no significant difference in the thickness at selected points on the ramus; at the mid-point of the ramus, at half-way between condylion and mid-point ramus and at half-way between goinion and mid-point ramus for males and females ($p>0.05$) with moderately strong positive correlations of 0.672, 0.633 and 0.684 respectively. There were significant differences between the right and left sides of the mandible at these points ($p<0.05$) with moderately strong positive correlations of 0.734, 0.695 and 0.746 respectively. Significant differences were noted between the screws and the thickness at these points with plate thickness added ($p<0.05$) with weak and very weak correlations of 0.169, 0.081and 0.027 respectively, as shown in Table 8.

Table 8. Thickness of the ramus without plate thickness added and with plate thickness added (highlighted).

Sex of the mandible		At mid-point ramus (With plate thickness added)		Half-way between condylion and midpoint ramus (With plate thickness added)		Half-way between gonio and mid-point ramus (With plate thickne added)	
		Right	Left	Right	Left	Right	Le
Male	Mean	5.96	5.81	6.66	7.00	5.81	5.7
(n=48)		(9.06)	(8.91)	(9.76)	(10.10)	(8.91)	(8.86
	S.D	1.04	.96	1.06	1.02	1.22	1.3
Female	Mean	6.05	5.75	6.32	6.37	5.92	5.5
(n=34)		(9.15)	(8.85)	(9.42)	(9.47)	(9.02)	(8.63
	S.D	1.00	.99	1.03	.88	1.01	1.1

Combined mean thickness of male and female at mid-point ramus=5.99±0.98, halfway condylion and midpoint ramus= 6.52±1.05, halfway goinion and midpoint ramus=5.87±1.10

At mid-point ramus-Male and female $r=0.672$, $p>0.05$. Right and left sides $r=0.734$, $p<0.05$*. Screw size $r=0.169$, $p<0.05$*.

At half-way between condylion and mid-point ramus- Male and female $r=0.633$, $p>0.05$. Right and left sides $r=0.695$, $p<0.05$*. Screw size $r=0.081$, $p<0.05$*.At halfway between gonion and mid-point ramus-Male and female $r=0.684$, $p>0.05$. Right and left sides $r=0.746$, $p<0.05$*. Screw size $r=0.027$, $p<0.05$*.

The width of the plates was 8mm and the height of the mental foramen from the lower border was obtained as shown in Table 10. This was to show whether the plate could impinge on the mental nerve when it is applied during reconstruction. There was no significant difference between the male and female measurements ($p>0.05$) with a strong positive correlation of 0.814.

Table 9. Height from the lower border of the mandible to mental foramen

Sex of the mandible		Right	Left
Male	Mean	13.78	13.81
(n=48)	S.D	1.46	1.32
Female	Mean	12.95	12.99
(n=34)	S.D	1.38	1.12

Combined mean for males and females = 13.39mm

$r=0.814$, $p>0.05$.

CHAPTER 4

4.1 DISCUSSION

The present study has provided baseline average linear dimensions and thicknesses at various levels of the of the Kenyan mandibles mainly from two ethnic groups. There was a significant difference in the size of the mandible between males and females, comparable to similar studies.[24,28,44,45] Significant differences between the right and left sides of the mandible comparable to other studies were present, which may be due to individual functional habits.[34,35,36] However, one study did not show significant differences between the right and left sides of the mandible.[20] Variations in population groups are also shown when the results of mandibular measurements are compared with others.[20,24,46,47] In the present study the mandibular length was 96.5mm, higher than in the Nigerians (92.7mm) [20] and Zimbabweans (77.3mm).[21] The mandibular height in the present study (54.9mm) was lower compared to the Nigerains (55.8 mm) and Zimbabweans (61.3mm). [24] The mean for the mandible of the Romanians (male114 mm) and (female 91 mm) are higher in males but lower for females compared to the present study.

The present study attempts to place emphasis on direct mandibular measurements, as the ones obtained radiologically have been found to be unreliable.[26,27,29,32,33,34,36] Measurements made from panoramic radiographs involve methodological error because of the magnification factor due to the position of the object between the x-ray source and the film. In addition there is a variety of panoramic x-ray machines and the amount of magnification.[26,32,33,36] However, accurate mandibular measurements can be taken using 3-dimensional (3-D) CT-scans as shown by Nasel et al.[27] and Hanazawa et al.[29] , although these may not be readily available in developing countries.

The sizes of Kenyan mandibles in the present study were not comparable with the average sizes of reconstruction plates. The full mandibular plates are shown to be smaller than the average total length of the mandible. Appropriate selection can be made from the range

supplied in sets. Due to financial constraints, in our set-up, patients are advised to obtain individual units of plates when reconstruction is indicated. Thus, average mandibular dimensions would be useful in prescribing the stated plates. The average thickness of the mandible at specific sections would guide in obtaining appropriate screws to support the plates.

The size of the reconstruction plates is important in planning of the surgical management of the defect which could be aided by baseline mandibular measurements. Yoshiya et al.[48] gave an analysis of reconstruction of mandibular defects using stainless steel plates and found them to have been stronger than the titanium ones. Kimuya et al.[49] assessed the stability of plates and emphasized on adequate size and number of screws. The screws should be bicortical with slight extension that would not damage the medial structures. Simon et al.[50] reviewed reconstruction of the mandible after ablative surgery for the treatment of aggressive benign odontogenic tumours, showing the size of the defect to have been most important. Hanen[51] assessed the recreation of the original contour of the mandible deformed by tumours and suggested on plate adapatation. Long-term outcome and factors influencing bridging plates for reconstruction of the mandible, are the size of the defect and type of material used.[52,53] Mehta and Descher[15] reviewed different techniques in mandibular reconstruction. Bone grafting with microvascular techniques are the ideal choice but have limitations. Thus, alloplastic plates were still recommended for use in mandibular reconstruction.[15] With the changing technology an assessment of the plate used in mandibular reonstruction concluded that the use of stainless steel plates was an acceptable method of restoring defects.[54,55]

Adult mandibles from two Kenyan ethnic groups were used to obtain average linear dimensions that may be used for appropriate plate selection, for surgical management of the defect. The average thickness of the mandible at various sections can be used for the selection of screws taking into consideration the thickness of the plate.

4.2 CONCLUSIONS:

The present study provides data on the average length of the body, the height of the ramus together with thicknesses at various sections of the mandible in Kenyan adults. This information is useful in selecting or modifying mandibular reconstruction plates as well as relating to defects and future research purposes. Mandibular morphometric variations compared with other population groups were observed. There were significant differences in the mandibular parameters between male and female mandible parameters as well as right and left sides. The size of the mandible showed weak correlations with that of the reconstruction plates.

4.3 RECOMMENDATIONS:

- Clinicians can use the baseline average dimensions of the mandible in selecting reconstruction plates and screws.

- A further study for a comparing the data obtained from direct measurement of the mandibles with that from standardized panoramic x-rays of similar mandibles could be carried out in order to determine the actual sizes of the mandible from radiographs.

- Where available, the use of 3-D CT-scans should be used to take accurate measurements of the mandible when reconstruction is indicated.

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APPENDICES.

Appendix 1

Data collection chart

Case Number :

Gender: M F

	Right	Left
Body length (mm)		
Ramus height (mm)		
Body thickness (mm)		
i) at symphysis		
ii) at canine		
iii) at mental foramen		
iv) at bifurcation of 1st molar		
v) at bifurcation of 2nd molar		
vi) at level of anterior ramus		
Thickness of ramus		
i) at mid-point of ramus		
ii) halfway betweeen condylion to midpoint ramus		
iii) halfway between midpoint ramus and gonion		
Height from lower border to mental foramen		

Appendix 2

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Ref: KNH-ERC/ 01/ 4506

3rd July 2007

Dr. Anthony O. Kenyanya
Dept. of Oral & Maxillofacial Surgery
School of Dental Sciences
University of Nairobi

Dear Dr. Kenyanya

REVISED RESEARCH PROPOSAL: "MORPHOMETRIC CORRELATION OF KENYAN ADULT MANDIBLES WITH RECONSTRUCTION IMPLANTS" (P77/4/2007)

This is to inform you that the Kenyatta National Hospital Ethics and Research Committee has reviewed and **approved** your above revised research proposal for the period 3rd July 2007 – 2nd July 2008.

You will be required to request for a renewal of the approval if you intend to continue with the study beyond the deadline given. Clearance for export of biological specimen must also be obtained from KNH-ERC for each batch.

On behalf of the Committee, I wish you fruitful research and look forward to receiving a summary of the research findings upon completion of the study.

This information will form part of database that will be consulted in future when processing related research study so as to minimize chances of study duplication.

Yours sincerely

PROF. A.N. GUANTAI
SECRETARY, KNH-ERC

c.c. Prof. K.M. Bhatt, Chairperson, KNH-ERC
The Deputy Director CS, KNH
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