Original article

Calvarial Thickness of the Nepalese Dry Skulls

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Abstract

Introduction: Calvarium of skull comprises frontal,parietal and occipital bone.These bones cap over the brain in cranial cavity. These bones are flat bones having outer and inner tables made up of compact bone. There is cancellous bone called as diploe in between the outer and inner table. The aim was to measure the thickness of calvaria at various points on Nepalese skull and establish Nepalese database of calvarial thickness and also to compare thickness on the right and left side for bilateral points.

Methods: Around140 calvaria of dried skull were studied. Thickness of various points on the frontal,parietal and occipital bones that form calvaria were measured with spreading caliper.The inner table,diploe and outer table thickness were measured with vernier caliper.

Results: The mean thickness of frontal bone is 5.6 ± 0.8 mm;out of which the outer table 1±0.2mm, the inner table 0.8±0.3mm and the diploe 3.8±0.6mm.The mean thickness of parietal bone is 4.5±0.6 mm;out of which the outer table 0.8±0.2mm, the inner table 0.6±0.2mm and the diploe 3.1±0.4mm. The mean thickness of occipital bone is 8.5±0.7 mm;out of which the outer table 2.2±0.4mm, the inner table 1±0.3mm and the diploe 5.7±0.6mm.There is significant difference in the mean thickness of the frontal, parietal and occipital bone($p<0.05$).

Theoverallmean thickness of the calvarium is 6.5±0.7 mm;out of which the outer table 1.5±0.3mm, the inner table 0.8±0.2mm and the diploe 4.5±0.5mm.The outer table is significantly thicker than the inner table($p<0.05$).

Conclusion: All these results indicate that the calvarium is not uniform in thickness and there is increased thickness towards the posterior and the outer table is thicker than the inner table.

Keywords: calvarium,outer table,diploe,inner table

Introduction

Calvarium of skull comprises thefrontal, parietal and occipital bone.These bones cap over the brain in cranial cavity.Thus surgeons approach the cranial cavity and its contents like the brain by taking out the respective part of the calvarial bone.The thickness of calvarial bones is not uniform.It varies from bone to bone and from point to point within a bone.

These bones are flat bones having outer and inner tables made up of compact bone.There is cancellous bone called as diploe in between the outer and inner table. Thus the thickness of calvarial bone is the sum of the thickness of the inner table, the diploe and the outer table. These bones are united by fibrous joints called sutures.

Calvarium is adonor site for bone grafting.Following craniotomy during neurosurgical procedure or reduction in case of fractures the surgeon may need to fix mini bone plates on cranium for immobilization of calvarial bones.

There is no recorded database of the thickness of Nepalese skullthus there is a need to carry out this research.The findings of this research will be useful for researchers,surgeons while planning the cranium as donor site for bone graft and determine the screw length while fixing bone plate on cranium.

Objectives

1. To measure the thickness of calvaria at various points on the Nepalese skull and establish Nepalese database of the calvarial thickness.

2. To compare the thickness on the right and left side for bilateral points.

Research hypothesis

There may be no difference in thickness of bones of calvarium between the right and left side.

Methods

Around 140 calvaria of dried skull were studied. Thickness of various points onfrontal, parietal and occipital bones that form calvaria were measured with spreading caliper.The inner table,the diploe and the outer table thickness were measured withvernier calipers.

The thickness of various points onthe frontal bone to be measured were (see figure 1, 2 &3):-

F1=Frontal tuberosity thickness (F1R=Right side frontal tuberosity thickness and F1L=Left side frontal tuberosity thickness)

F2=Mid point between two tuberosities

F3=4 cm lateral to frontal tuberosity(F3R=Right side and F3L=Left side)

F4=Thickness of frontal bone towards pterion(F4R=on right side,F4L=on left side)

F5=2 cm posterior to F2

F6=3 cm lateral to F5(F6R=on right side,F6L=on left side)

F7=4 cm posterior to F2

F8=4 cm lateral to F7(F8R=on right side,F8L=on left side)

F9=6 cm posterior to F2 or near to bregma point.

Thickness of various points onthe parietal bone to be measured were (see figure 4) :-

P1=Parietal eminence thickness (P1R=on right side and P1L=on left side)

P2=Parietal bone near tobregma

P3=Mid point at sagittal suture

P4=3 cm lateral toP1(P4R=on right side,P4L=on left side)

P5=Parietal bone near tolamda

P6=3 cm cranial topterion(P6R=on right side and P6L=on left side)

P7=4 cm lateral to P5(P7R=on right side and P7L=on left side)

P8=3 cm cranial to asterion(P8R=on right side,P8L=on left side)

Thickness of various points onthe occipital bone to be measured were (see figure 5) :-

O1=1 cm posterior to lamda on midline

O2=2 cm posterior to lamda on midline

O3=2 cm postero-lateral to lamda(O3R=on right side,O3L=on left side)

O4=4cm posterior to lamda

O5=3 cm lateral to O4(O5R=on right side,O5L=on left side)

O6=near toexternal occipital protuberance

Statistical analysis

All data were entered into computer using Microsoft windows' access software and after purification of data,analysis was done using SPSS (Statistical Package for Social Sciences) version 11:00 software. The average value of thickness at various points was calculated and right and left side thickness was compared for bilateral points.Student's unpaired "t" test was used to test the significance for any bilateral variation in thickness.One way ANOVA test was applied to test the significance difference among various points on each bone and among the mean thickness of the frontal, parietal and occipital bones.Statistical significance was considered at 95% confidence interval ($p<0.05$).

Results

One hundred and fourtycalvaria were studied.Nine various points on the frontal bone,eight onthe parietal and six on the occipital were located and their thickness was measured.The points falling on the mid-sagittal line are unilateral points and those points falling aside are bilateral points which are specified as right and left side.For the unilateral points only airthmatic mean and standard deviation were calculated where as for bilateral points inaddition to calculation of airthmatic mean and standard deviation,unpaired "t"test was applied to test significant difference between the right and left side points.In all cases, there was no significant difference between the right and left side points($p>0.05$). One way ANOVA test was applied to test the significant difference among various points on each bone and among the mean thickness of the frontal, the parietal and the occipital bones. There was significant difference ($p<0.05$) in thickness among various points on each bone in all cases.The result showed that the posterior part of the bones was significantly thicker than the anterior part, i.e.,F9 is thicker than F3 and F4,O6 is thicker than O3 and O5,P5 is thicker than P4,P6 and P7($p<0.05$).There was significant difference in mean thickness of the frontal,the parietal and the occipital bones($p<0.05$).

The airthmatic mean and standard deviation of thickness for various points on the calvarium are tabulated below:-

Table 1. Mean thickness of frontal bone at various points

SN	Points of observation	Mean thickness(mm)±SD
1.	F1R=Right side frontal tuberosity thickness	5.5±1.4
2.	F1L=Left side frontal tuberosity thickness	5.4±1.4
3.	F2=Mid point between two tuberosities	6.2±1.9
4.	F3R=4 cm lateral to frontal tuberosity on the right side	4.3±1.2
5.	F3L=4 cm lateral to frontal tuberosity on the left side	4.4±1.2
6.	F4R=Thickness of frontal bone towards pterion on the right side	3.8±1.3
7.	F4L=Thickness of frontal bone towards pterion on the left side	3.9±1.2
8.	F5=2 cm posterior to F2	6.4±1.7
9.	F6R=3 cm lateral to F5 on the right side	5.8±1.2
10.	F6L=3 cm lateral to F5 on the left side	5.7±1.3
11.	F7=4 cm posterior to F2	6±1.3
12.	F8R=4 cm lateral to F7 on the right side	6±1.8
13.	F8L=4 cm lateral to F7 on the left side	6.2±1.9
14.	F9=6 cm posterior to F2 or near to bregma point	6.8±1.8

There was significant difference($p<0.05$) in thickness among various points on the frontal bone.The result showed that the posterior part of the bones was significantly thicker than the anterior part, i.e,F2,F7,F8 and F9 is thicker than F3 and F4.

The mean and standard deviation of thickness of the frontal bone wascalculated as 5.6±0.8 mm;out of which the outer table 1±0.2mm,theinner table0.8±0.3mm and the diploe 3.8±0.6mm.

Table 2. Mean thickness of parietal bone at various points

SN	Points of observation	Mean thickness(mm)±SD
1.	P1R=Parietal eminence thickness on the right side	4±1.4
2.	P1L=Parietal eminence thickness on the left side	4.1±1.3
3.	P2=Parietal bone near to bregma	6.6±1.5
4.	P3=Mid point at sagittal suture	6.5±1.7
5.	P4R=3 cm lateral to P1 on the right side	4.2±1.2
6.	P4L=3 cm lateral to P1 on the left side	4.1±1.1
7.	P5=Parietal bone near to lamda	7.5±1.1
8.	P6R=3 cm cranial to pterion on the right side	3±1.8
9.	P6L=3 cm cranial to Pterion on the left side	3.2±1.9
10.	P7R=4 cm lateral to P5 on the right side	4.2±1.6
11.	P7L=4 cm lateral to P5 on the left side	4.1±1.6
12.	P8R=3 cm cranial to asterion on the right side	4.6±1.8

There was significant difference($p<0.05$) in thickness among various points on the parietal bone.The result showed that P2,P3 and P5 were significantly thicker than P1,P4,P6,P7 and P8($p<0.05$).The posterior part of the bones was significantly thicker than the anterior part i.e.P5 was thicker than P1,P4,P6 and P7 ($p<0.05$).

The mean and standard deviation of thickness of the parietal bone was calculated as 4.5±0.6 mm;out of which the outer table 0.8±0.2mm,theinner table0.6±0.2mm and the diploe 3.1±0.4mm.

Table 3. Mean thickness of occipital bone at various points

SN	Points of observation	Mean thickness(mm)±SD
1.	O1=1 cm posterior to lamda	8±1.3
2.	O2=2 cm posterior to lamda on midline	10±1.2
3.	O3R=2 cm postero-lateral to lamda on the right side	6.2±1.8
4.	O3L=2 cm postero-lateral to lamda on the left side	6.3±1.9
5.	O4=4cm posterior to lamda	11±1.4
6.	O5R=3 cm lateral to O4 on the right side	5.3±1.6
7.	O5L=3 cm lateral to O4 on the left side	5.2±1.7
8.	O6=near to external occipital protuberance	11.5±1.5

There was significant difference ($p<0.05$) in thickness among various points on the occipitalbone. The result showed that O2,O4 and O6 were significantly thicker than O1,O3 and O5 ($p<0.05$).The posterior part of the bones was significantly thicker than the anterior part i.e. O6 was thicker than O3 and O5 ($p<0.05$).

The mean and standard deviation of thickness of the occipital bone was calculated as8.5±0.7 mm;out of which the outer table 2.2±0.4mm, the inner table 1±0.3mm and the diploe 5.7±0.6mm.

Table 4. Comparision of mean thickness of frontal,parietal and occipital bones

Thickness	Frontal bone	Parietal bone	Occipital bone	P value
Mean thickness(mm)±SD	5.6±0.8 mm	4.5±0.6 mm	8.5±0.7 mm	0.047

There was significant difference among mean thickness of the frontal, the parietal and the occipital bones ($p<0.05$).

Table 5. Comparision of mean thickness of outer and inner tables

Thickness	Outer table	Inner table	P value
Mean thickness(mm)±SD	1.5±0.3mm	0.8±0.2mm	0.041

There was significant difference ($p<0.05$) between mean thickness of the outer and inner tables.

The over allmean and standard deviation of thickness of the calvarium was6.5±0.7 mm;out of which the outer table 1.5±0.3mm, the inner table 0.8±0.2mm and the diploe 4.5±0.5mm. The outer table was significantly thicker than the inner table ($p<0.05$).

Discussion

Moreira-Gonzalez et.al studied calvarial thickness and found a statistically significant pattern of increased thickness towards the posterior parietal bones in all subjects. The mean thickness of the skull across all locations was 6.32mm_+0.7mm.Age was not found to be a significant predictor of mean skull thickness. Differences between male and female skulls were greater toward the rear of the parietal bones.[1]

The present study result also showed the significant variation in thickness at various points within a bone($p<0.05$).The posterior points are significantly thicker than the anterior points,i.e.,F9 is thicker thanF3 and F4,O6 is thicker than O3 and O5,P5 is thicker than P4,P6 and P7($p<0.05$). The overall mean thickness of the frontal bone is 5.6±0.8 mm, the parietal bone 4.5±0.6 mm and the occipital bone 8.5±0.7 mm respectively. The mean thickness of the calvarium is 6.5±0.7 mm.

Reher P and Duarte GC carried out anatomic study in fronto-zygomatic region and measured thickness to determine the length of screw that can be used without a risk of penetrating the cranial cavity.Their results showed that above the fronto-zygomatic suture 5mm screws could be used and below the suture 7mm screw could be used.[2]

Ross MD et.al investigated the skull thickness of Black and White races and found that White women have the thickest and White men the thinnest skulls. The skulls of women were statistically significant thicker than those of men in both ethnic groups.[3] Ross AH et.al had done research on cranial thickness in American females and males with an objective to examine sex and age variation in cranial thickness in a white sample. An increase in cranial thickness with age was observed.[4]Hwang K et.al carried out thickness mapping of the parietal bone in Korean adults and concluded that the parietal bone tended to be thicker towards the lamda point than at the coronal suture area.[5]

The present study result also found similar finding that parietal bone toward coronal suture, i.e. bregma point is 6.5mm and toward lamda point is 7.5 mm. This difference is statistically significan t($p<0.05$).

Gerhard W. Weber et.al carried out thickness mapping of the occipital bone on CT-data and opined that information about the thickness of cranial bones is not only of great medical interest, particularly for pre-operative surgical planning, but can be useful for investigations of fossil hominid material.[6] Jill Peterson et.al analyzed material properties of the inner and outer cortical tables of the human parietal bone and revealed that the outer table was on average thicker, denser and stiffer than the inner table.[7]

Similar to the finding of Jill Peterson et.al the present study also revealed the fact that the outer table is significantly thicker than the inner table($p<0.05$) as mean thickness of the outer table is 1.5±0.3mm and that of the inner table is 0.8±0.2mm.

Pensler J and MC Carthy JG had done study on 200 fresh adult cadavers and measured thickness at selected points and concluded that age, height, weight, sex and race had no significant effect oncalvarial thickness.[8]

Adelove A et.al studied on the thickness of the normal skull in the American Blacks and Whites and observed that the frontal bone is thicker in White male than in Black where asParieto-Occipital is thicker in Blacks than in Whites. In certain age groups, the females in both races have significantly thicker parietal and occipital bones than their male counterparts.[9]Gratz KW et.al performed research on the mandibular reconstruction with full thickness calvarial bone and temporal muscle flap.[10]Samuel K.Law studied thickness and resistivity variations over the upper surface of the human skull

and suggested that the skull cannot be considered a uniform layer and local resistivity variations should be incorporated into realistic head models.[11]

The present study result also proved that the constituent bones of the calvarium differ in thickness significantly as well as various points within a bone also differ in thickness significantly.

The thickness of calvarial bones depends on structure and functions (physiology) of underlying brain.

Conclusion

One hundred and fourtycalvaria were studied. Nine various points on the frontal bone, eight on the parietal and six on the occipital were located and their thickness as well as thickness of the outer table, the diploe and the inner table were measured.The points falling on the mid-sagittal line are unilateral points and those points falling aside are bilateral points which are specified as right and left side.For the unilateral points only arithmetic mean and standard deviation were calculated; where as for bilateral points inaddition to calculation of arithmetic mean and standard deviation, paired "t"was applied to test significant difference in thickness between right and left side points. In all cases there is no significant difference between the right and left sidepoints ($p>0.05$). One way ANOVA test was applied to test the significant difference among various points on each bone and among the mean thickness of the frontal, the parietal and the occipital bones.

There was significant difference ($p<0.05$) in thickness among various points on each bone in all cases. The posterior points are significantly thicker than the anterior points, i.e,.F9 is thicker than F3 and F4;O6 is thicker than O3 and O5; P5 is thicker than P4,P6 and P7($p<0.05$).

The mean thickness of the frontal bone is 5.6±0.8 mm; out of which the outer table 1±0.2mm, the inner table 0.8±0.3mm and the diploe 3.8±0.6mm. The mean thickness of the parietal bone is 4.5±0.6 mm; out of which the outer table 0.8±0.2mm, the inner table 0.6±0.2mm and the diploe 3.1±0.4mm.The mean thickness of the occipital bone is 8.5±0.7 mm; out of which the outer table 2.2±0.4mm, the inner table 1±0.3mm and the diploe 5.7±0.6mm. There is significant difference in mean thickness of the frontal, the parietal and the occipital bones($p<0.05$).

The over all mean thickness of the calvarium is 6.5±0.7 mm; out of which the outer table 1.5±0.3mm, the inner table 0.8±0.2mm and the diploe 4.5±0.5mm. The outer table is significantly thicker than the inner table($p<0.05$).

All these results indicate that the calvarium is not uniform in thickness and there is increased thickness towards posterior and the outer table is thicker than the inner table.

Conflict of interests: None Declared

References

1. Moreira-Gonzalez Andrea MD, Papay, Francis EMD, Zins and James EMD Calvarial thickness and its relation to cranial bone harvest. Plastics and reconstructive surgery. 2006; 117(6):1964-1971.
2. Reher P and Duarte GC. Miniplates in the frontozygomaticregion. An anatomic study. J Anat.2000; 197:61-76.
3. Ross MD, Lee KA and Castle WM. Skull thickness of Black and White races. SAfr Med J 1976; 50(16):635-8.
4. Ross AH, Jantz RL and McCormick WF. Cranial thickness in American females and males. J Forensic Sci1998; 43(2):267-72.
5. Hwang K, Kim J Hand Baik SH. Thickness mapping of the parietal bone in Korean adults.J.Craniofac. Surg1997; 8:208-12.
6. Weber GW, Johann K, Arnold N. Cassian C, Magori, Charles B, Saanane and Wolfagang. Thickness mapping of the occipital bone on CT-data. ActaAnthropologicaSinica Supplement 2000; 19:37-46.
7. Peterson J, Paul C and Dechow. Material properties of the inner and outer cortical tables of the human parietal bone.Anat Rec2008; 268:7-15.
8. PenslerJ, McCarthy JG. The calvarial donor site: an anatomic study in cadavers. PlastReconstrSurg 1985; 75(5):648-51.
9. Adelove A, Kattan KR and Silverman FN. Thickness of the normal skull in the American Blacks and Whites.AM J PhysAnthropol 1975; 43(1):23-30.

10. Gratz KW, Sailer HF, Haers PE and Oecholinck. Mandibular reconstruction with full thickness calvarial bone and temporal muscle flap.Br.J Oral maxillofacSurg1996;34(5):379-85.

11. Samuel K Law. Thickness and resistivity variations over the upper surface of the human skull. Coll Anthropol1999; 23(2)333-43.

Presentation of figures:

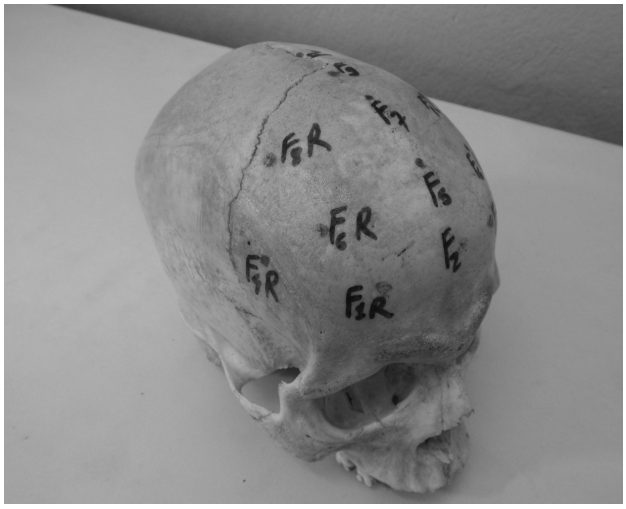

Fig 1. The measured points on midline and right side frontal bone.

F1=Frontal tuberosity thickness(F1R=Right side frontal tuberosity thickness and F1L=Left side frontal tuberosity thickness)

F2=Mid point between two tuberosities

F3=4 cm Lateral to frontal tuberosity(F3R=Right side and F3L=Left side)

F4=Thickness of frontal bone towards pterion(F4R=on right side,F4L=on left side)

F5=2 cm Posterior to F2

F6=3 cm Lateral to F5(F6R=on right side,F6L=on left side)

F7=4 cm Posterior to F2

F8=4 cm Lateral to F7(F8R=on right side,F8L=on left side)

F9=6 cm Posterior to F2 or near to Bregma point.

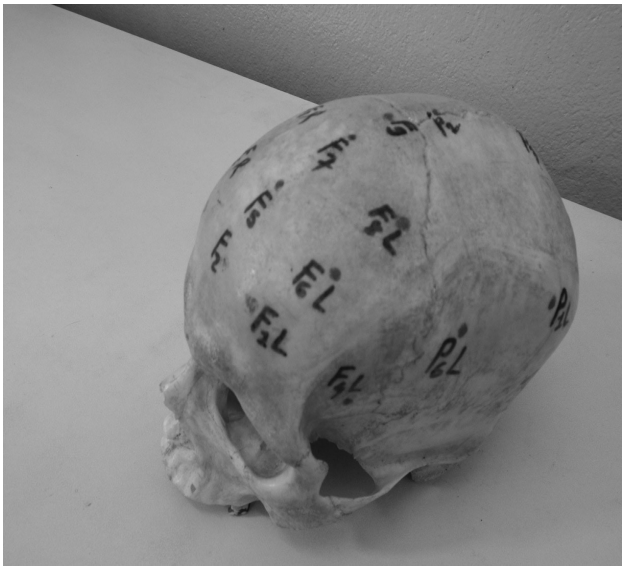

Fig 2. The measured points on midline and left side frontal bone.

F1=Frontal tuberosity thickness(F1R=Right side frontal tuberosity thickness and F1L=Left side frontal tuberosity thickness)

F2=Mid point between two tuberosities

F3=4 cm Lateral to frontal tuberosity(F3R=Right side and F3L=Left side)

F4=Thickness of frontal bone towards pterion(F4R=on right side,F4L=on left side)

F5=2 cm Posterior to F2

F6=3 cm Lateral to F5(F6R=on right side,F6L=on left side)

F7=4 cm Posterior to F2

F8=4 cm Lateral to F7(F8R=on right side,F8L=on left side)

F9=6 cm Posterior to F2 or near to Bregma point.

Fig 3: The measured points on midline and some part of both right and left side frontal bone.

F1=Frontal tuberosity thickness(F1R=Right side frontal tuberosity thickness and F1L=Left side frontal tuberosity thickness)

F2=Mid point between two tuberosities

F3=4 cm Lateral to frontal tuberosity(F3R=Right side and F3L=Left side)

F4=Thickness of frontal bone towards pterion(F4R=on right side,F4L=on left side)

F5=2 cm Posterior to F2

F6=3 cm Lateral to F5(F6R=on right side,F6L=on left side)

F7=4 cm Posterior to F2

F8=4 cm Lateral to F7(F8R=on right side,F8L=on left side)

F9=6 cm Posterior to F2 or near to Bregma point.

Fig 4: The measured points on midline and left side parietal bone.

P1=Parietal eminence thickness(P1R=on right side and P1L=on left side)

P2=Parietal bone near to Bregma

P3=Mid point at Sagittal Suture

P4=3 cm Lateral to P1(P4R=on right side,P4L=on left side)

P5=Parietal bone near to Lamda

P6=3 cm Cranial to Pterion(P6R=on right side and P6L=on left side)

P7=4 cm Lateral to P5(P7R=on right side and P7L=on left side)

P8=3 cm Cranial to Asterion(P8R=on right side,P8L=on left side)

Fig 5: The measured points on midline and both right and left side occipital bone.

O1=1 cm posterior to Lamda on midline

O2=2 cm posterior to Lamda on midline

O3=2 cm postero-lateral to Lamda(O3R=on right side,O3L=on left side)

O4=4cm posterior to Lamda

O5=3 cm lateral to O4(O5R=on right side,O5L=on left side)

O6=near to External Occipital protuberance