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RADIOLOGICAL STUDY OF MEASUREMENT OF THE SKULL TABLE THICKNESS BY USING COMPUTED TOMOGRAPHY (CT) SCAN IMAGES OF DIFFERENT AGE GROUPS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Introduction: Traumatic brain injury is one of the leading causes of death in adults. Accidental trauma and criminal acts account for about 25% and 10% of such head injuries respectively. A human biological system has evolved to protect and safeguard every organ and structure. The strength, consolidation, and solidarity of bone tissue are based on diversified factors like age, gender, nutritional status, genetic factors, lifestyle factors, etc. Barin is one such vital organ protected by compact skull bone covering all over it; hence various layers of skull bone thickness are a matter of anatomical concern to protect the brain in any crucial circumstances.

Methodology: The radiological study involving the 121 CT scan images of the skull of both males and females of age groups ranging from 18 to 80 years was used to study various layers of the calvarial thickness. The statistical analysis of various skull bone landmark point thicknesses of different ages and genders (male and female) was analysed by using independent samples t-tests.

Results: The outcome indicates no significant changes neither in the cranial outer table nor in the inner table, but changes were observed only with respect to the diploe of frontal bone statically coinciding with the female gender. The diploe layer of the frontal bone exhibits a significant difference ($p < 0.004$) with females having a thicker mean of 2.40 ± 1.43 compared to males with 1.78 ± 0.91 on the left side. **Conclusion**: The various skull-bony landmarks tables may not show much significant differences with respect to age or gender. The present study is a cross-sectional one, various factors are involved in maintaining bone strength and solidarity hence a longitudinal follow-up study outcome may meet much rational consensus.

Keywords: Computed Tomography (CT), skull-bony landmarks tables, Radiology

INTRODUCTION

The phenomenal growth in countries' economies, increasing population, urbanization, industrialization, and motorization factors are important concerns in increasing the incidences of head injuries. Such injuries may result in hospitalization, death, or disabilities especially which is jeopardizing the productive life span of a group of the young Indian population **[1]**. Skull is an important shell-like coverage of the brain, which act as a natural helmet protecting the brain. The skull forms the most important biological and personal identity of an individual; it is also important from the forensic anatomy standpoint. Developmentally the skull bones are made of mesodermal germ layer and neural crest cells. The neurocranium forms the calvaria (vault) of the skull, and the splanchnocranium forms the facial skeleton of the skull. Skull develops from intramembranous and endochondral ossification. The skull bones are connected through fibrous articulations; it is supported by sutural ligaments forming various static sutural joints **[2]**. Calvaria or vault of skull thickness is also important in dealing with various craniofacial reconstructive surgeries **[3]**. The vascularity of the brain and skull is maintained by the branches of the carotid and vertebral arteries. Its venous drainage is maintained through various dural venous channels called sinuses. Diploic veins are valveless veinous shunts occupying the space between the compact bone forming the inner table and outer table of the surface of the skull. They drain the venous blood into the cranial venous sinuses through the emissary's veins. Later also play role in the reabsorption of cerebrospinal fluid. Diploe veins communicate between extra and intra-cranial venous channels **[4]**. Traumatic brain injury (TBI) is a major public concern in India. In India violation of traffic rule of wearing the helmet among the two wheelers may account for 60% of road traffic related head injuries. Accidental fall and criminal assaults may account 25% and 10% of such head injuries respectively **[5]**. The CT scan is more commonly used radiological investigation to evaluate the traumatic brain injuries (TBI). Hence the thickness measurement of calvaria inner and outer compact tables, and intervening diploe at various regions of skull bones through CT scan is important in evaluation of various form of traumatic skull injuries, hematoma formation, brain tissue damage and reconstructive surgical grafting procedures **[6]**.

Hypothesis: the skull bone thickness discrimination occurs according to the age and sex of an individual.

Objective: to study the characterisation of the skull bone thickness in various age groups

Inclusion criteria: subjects males and females who belong to age between above18 years -80 years of age.

Exclusion criteria: CT scan with trauma

METHODOLOGY

The present study was conducted on 121 CT scan images (75 males and 46 females) collected from KVC Diagnostic Centre Mysore. Reports were procured randomly based on the suitability of Age and gender, through online mode and the images were analysed through online scale, later the data was entered into the excel sheet. Subjects, with the CT of age above 18 years to 80 years were taken. Any subjects with any underlying pathology like fractures or any underlying intracranial lesions were excluded from the study. CT images of Bone window of the head region were taken using Siemens 16 slice, German device. The in-plane resolution for each scan ranged from 0.488 to 0.625mm with a maximum slice thickness of 0.625mm.

The skull bone thickness was assessed and measured by only one investigator of the study throughout the research. Using the axial view of CT head, the thickness of various bones was measured. The thickness of parietal bone was measured at level of the highest point of parietal protuberance. The frontal thickness was measured at the midpoint between frontal crest and the coronal suture. The thickness of the parietal bone was measured at the level of highest point of parietal protuberance. The temporal and occipital full thickness was measured at the level of mastoid hair cells. The temporal bone thickness was measured at the mid of the temporal bone in front of the mastoid process. The occipital thickness was measured at the mid of the occipital bone lateral to the internal occipital protuberance **[7]**. In frontal and parietal bones outer table, inner table and diploe thickness was measured separately. In temporal and occipital bone as the diploe is very thin hence the full thickness was measured. All four parameter measurements were recorded in millimetre, photos were taken and readings were tabulated and statistical analysis was done **(Figure 1)**.

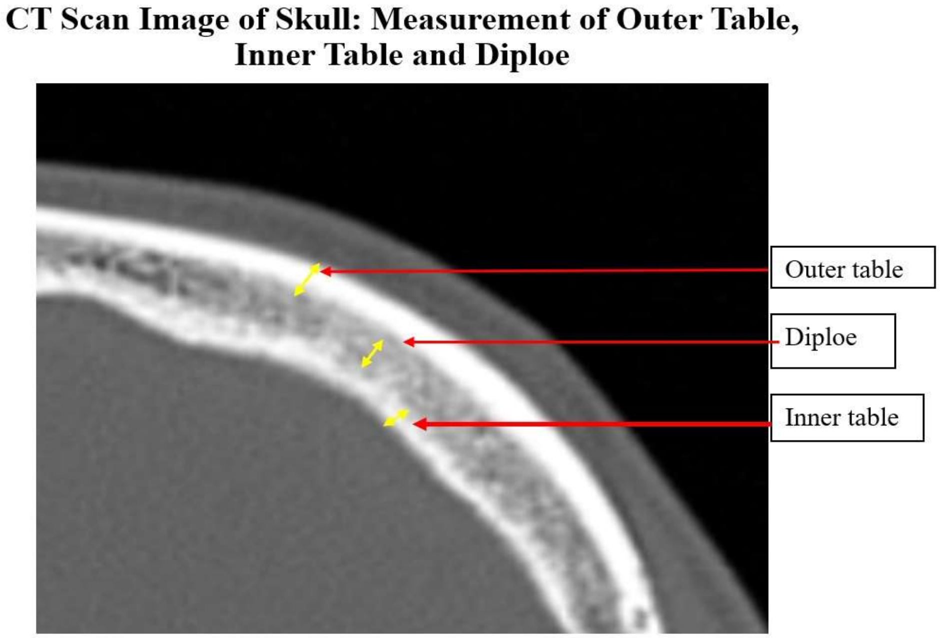

Figure 1

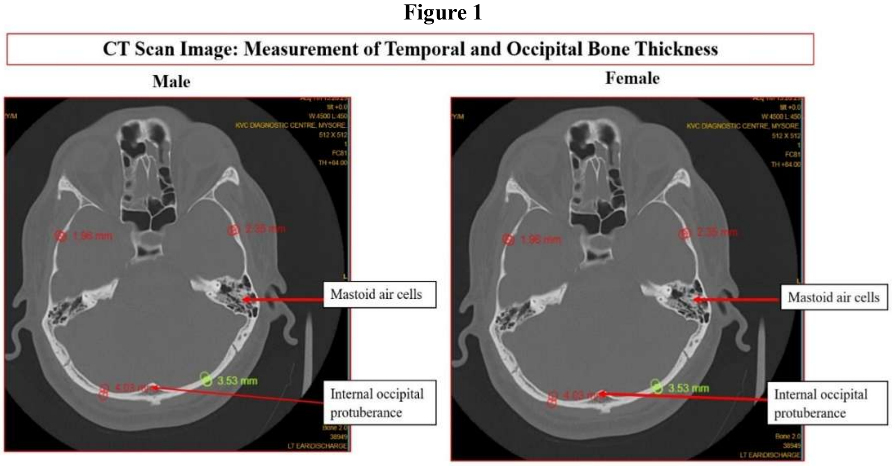

Figure 2

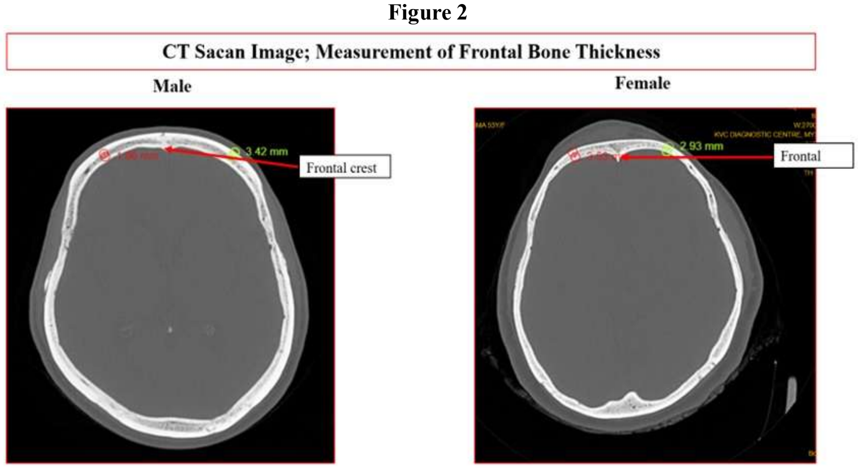

Figure 3

CT Scan Image: Measurement of Parietal Bone Thickness

Male **Female**

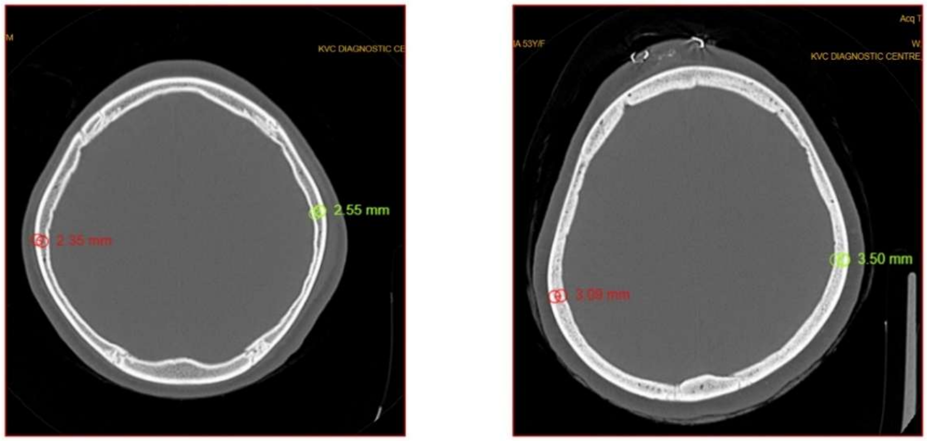

Figure 4

Statistical Analysis

A Normal Quantile plot and Histogram are used to assess a set of data follows a normal distribution. The parameters include the range, mean, and standard deviation for each region and subregion of the skull. The statistical analysis of skull thickness parameters and age differences between males and females was conducted using independent samples t-tests. For the skull thickness parameters, a series of unpaired t-tests were employed to compare means between males and females for each anatomical region at 5 % level of significance. The statistical analyses were conducted using IBM SPSS 22 software.

RESULTS

The statistical examination of skull thickness data across various regions and age groups has presented compelling insights into the varied thickness pattern. The data conforms to a normal distribution when analysed with a normal quantile plot shows in **Figure 5**. Among the 121 participants, 75 of them are male (62%), and 46 are female (38%). There are three age groups are considered in this study i.e. 18-35, 35-52, and >52. Among Females, 34.8% are in the 18-35 age group, 39.1% are in the 35-52 age group, and 26.1% are over 52. The study provides valuable insights into the intricate relationships between skull thickness, region, age, and gender.

The **Table 1** represents a statistical descriptive study of the variable associated with skull thickness across many regions, including the Frontal, Parietal, Temporal, and Occipital, divided into Innertable, Diploe, and Outertable layers. The range values of Skull thickness, which range from 2.93 to 130.56, show significant variation in both the statistical analysis of **Left and Right-side** Skull thickness across different locations and layers. The occipital region generally has the thickest skull, with a mean skull thickness of 6.14 and a standard deviation of 2.03 and the Parietal Innertable region having the lowest mean thickness (1.71) in left side.

In the Frontal region, the Innertable exhibits a mean of 1.24 with a relatively low standard deviation of 0.41 indicating consistent thickness. The Diploe and Outertable regions within the Frontal region also show reasonable consistency. In the Parietal region the Innertable shows a mean of 2.44 and a relatively high standard deviation of 8.78. The Diploe and Outertable regions in the Parietal region exhibit even greater variability. The Temporal region has a mean thickness of 3.50 and a moderate standard deviation of 1.13, while the Occipital region has the thickest skulls, with a mean of 6.01 and a standard deviation of 2.03. Overall, these statistics illustrate significant variability in ride side skull thickness across different regions.

The **Table 2** represents comparison between age groups and gender in skull thickness. In the 18-35 age group, females (27.75 ± 4.75) exhibit a slightly higher mean age than males (25.85 ± 4.64) although this difference is not statistically significant ($p = 0.21$). Similarly in the 35-52 age range males (42.28 ± 4.82) have a higher mean age compared to females (40.82 ± 3.84) with the difference are not statistical significance ($p = 0.30$). For individuals aged over 52 males (67.50 ± 9.89) and females (64.83 ± 7.96) again show numerical differences that are not statistically significant ($p = 0.44$). From these results shows that there were no significant differences between gender and age groups.

Among frontal structures, the diploe layer exhibits a significant difference ($p < 0.004$) with females having a thicker mean of 2.40 ± 1.43 compared to males with 1.78 ± 0.91. Parietal Innertable thickness shows a borderline non-significant trend ($p = 0.06$), and occipital thickness is significantly thicker in males ($p = 0.04$). Conversely, no statistically significant differences are observed in frontal and parietal Outertable, parietal diploe, temporal, and occipital structures at 5 % level of significance using unpaired t test shown in **Table 3**.

The **Table 4** represents analysis of skull thickness parameters between males and females in specific regions. In the frontal region, the diploe layer exhibits a highly statistically significant disparity ($p = 0.0001$), indicating that females (2.34 ± 1.45) have a significantly thicker diploe layer compared to males (1.82 ± 0.89). Conversely no significant differences are observed in the frontal Innertable and Outertable thicknesses. For the parietal region, while Innertable, diploe and Outertable thicknesses show no significant gender differences. Temporal thicknesses do not differ significantly between genders (p =

0.81) at 5 % level of significance. Notably occipital thickness exhibits a significant difference (p = 0.03), with males (6.32 ± 1.98) having a thicker mean compared to females (5.50 ± 2.04). These findings highlight region-specific variations in skull thickness with statistically significant differences observed in the frontal diploe and occipital regions.

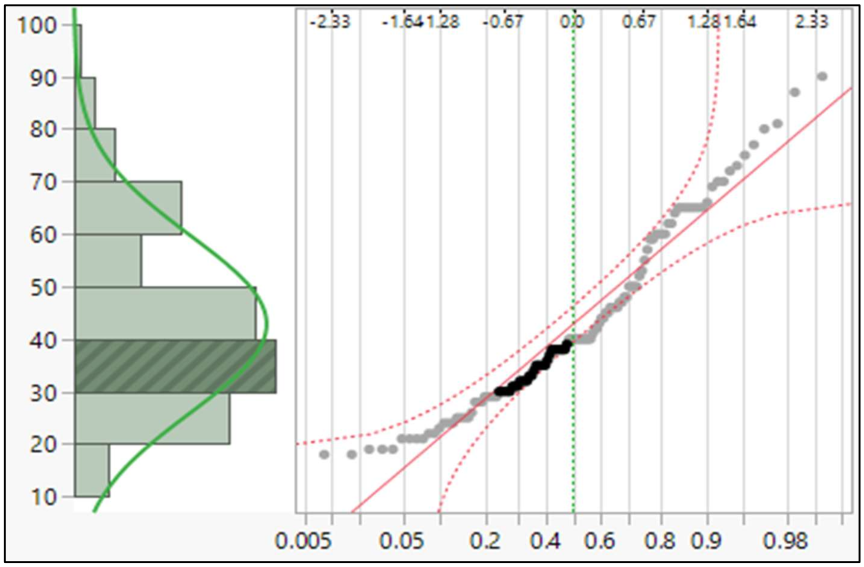

Figure 5: Normal Quantile Plot with Histogram for study population

Table 1: Descriptive Statistics for Left and Right-side Skull thickness

Skull thickness parameters		Left side			Right side		
		Range	Mean	SD	Range	Mean	SD
Frontal	Innertable	98.56	2.07	8.60	2.05	1.24	0.41
	Diploe	5.93	2.01	1.17	7.51	2.02	1.16
	Outertable	2.93	1.85	0.61	3.93	2.12	0.64
Parietal	Innertable	3.37	1.71	0.61	97.56	2.44	8.78
	Diploe	6.83	2.16	1.06	130.56	3.35	11.76
	Outertable	3.19	2.29	0.63	3.69	2.30	0.62
Temporal		6.23	3.40	1.19	6.1	3.50	1.13
Occipital		11.9	6.14	2.03	10.54	6.01	2.03

Table 2: Age and Gender comparison in skull thickness using independent t test

Age	Male	Female	p- value
	Mean ± SD	Mean ± SD	
18-35	25.85 ± 4.64	27.75 ± 4.75	0.21
35-52	42.28 ± 4.82	40.82 ± 3.84	0.30
> 52	67.50 ± 9.89	64.83 ± 7.96	0.44

Table 3: Gender-Based comparison of left Skull Thickness using independent t test

Skull thickness parameters		Male	Female	p-value
		Mean ± SD	Mean ± SD	
Frontal	Innertable	2.58 ± 11.29	1.24 ± 0.57	0.43
	Diploe	1.78 ± 0.91	2.40 ± 1.43	<0.004*
	Outertable	1.86 ± 0.59	1.83 ± 0.65	0.83
Parietal	Innertable	1.63 ± 0.56	1.84 ± 0.66	0.06
	Diploe	2.11 ± 0.99	2.24 ± 1.18	0.52
	Outertable	2.35 ± 0.63	2.19 ± 0.62	0.22
Temporal		3.33 ± 1.18	3.52 ± 1.23	0.46
Occipital		6.43 ± 2.11	5.66 ± 1.80	0.04*

Table 4: Gender-Based Analysis of right Skull Thickness

Skull thickness parameters		Male	Female	p-value
		Mean ± SD	Mean ± SD	
Frontal	Innertable	1.27 ± 0.40	1.20 ± 0.44	0.37
	Diploe	1.82 ± 0.89	2.34 ± 1.45	<0.0001*
	Outertable	2.11 ± 0.60	2.13 ± 0.72	0.84
Parietal	Innertable	2.91 ± 11.14	1.68 ± 0.65	0.46
	Diploe	4.04 ± 14.90	2.22 ± 1.15	0.41
	Outertable	2.38 ± 0.57	2.19 ± 0.69	0.10
Temporal		3.48 ± 1.17	3.54 ± 1.09	0.81
Occipital		6.32 ± 1.98	5.50 ± 2.04	0.03*

DISCUSSION

Traumatic brain injuries (TBI) may result in morbidity, disability, and mortality. Its complications are involving the neurological, psychological, or both the factors, which is taxing the common man with the heavy financial risk causing socioeconomic problem and health care burden on the society. Head bones will protect the brain from primary injury which is caused due to direct mechanical trauma to the skull. The secondary brain injury could be due to the indirect trauma due to the primary injury leading to variable degree of brain damage or death by involving tissues or derangement at the cellular level **[8]**. The female skull seems to be more prone to show subtle morphological variations with respect to epipteric pattern of bone presentations in the skull **[9]**. But surgically the male Indian population are more prone for traumatic incidences of head over female **[6]**. Cranial vault bone biopsy studies done by using X-rays in cadavers are showing that the men are having considerably thicker frontal bone dipole than the females. But it may not be showing much significant difference with respect to age, sex, and body weight. It is an important entity to be considered while assessing biomechanical remodeling of the vault **[10]**.

Physiologically diploic veins act as an alternate route of absorption of CSF which is a link between extracranial and intracranial venous channels which is traversing through inner and outer table of calvaria. These veins also pose potential risk of spreading the infections more towards intracranially due to its proximity with the dural venous sinuses **[11]**. A case of abnormal signal intensity in the region of frontal bone under MRI was showing the multiple connections from the branches of external carotid artery and middle meningeal artery was suggestive of diploic arteriovenous fistula with cortical venous reflux **[12]**.

The skull shows considerable modifications in various age groups and gender. The skull bone diploic venous porosity variation is important to understand the anatomical and biomechanical basis of traumatic brain injury. Skull bone is consolidated cortical bone sandwich of cancellous bone on either side. The susceptibility of head injury is based on the density of skull bone. It was found that females are more prone to traumatic head injuries which is having direct corelation with the advanced ageing. These qualitative changes probably because of the various biological factors which might be influencing the various structural entities. Flap of skull is having paramount importance from the point of surgical grafting, hence the thickness analysis of prominent locations of the skull is much rational. There are limited studies on the measurement of bone thickness attributing to the age factor and gender **[13]**.

The outer table of parietal calvaria is an important and preferred graft site for craniofacial reconstruction surgeries. Study tested the orthotropic and anisotropic properties of the calvaria morphology showing tensile and compressive properties which is essential to deal with its functional and accidental load on it. A study used longitudinal and transverse ultrasonic waves to reveal the outer and inner table of calvaria is exhibiting the difference in their density and mechanical properties **[14]**. Often, the damage to diploic veins can lead to subdural hematoma. Hence, the calvaria thickness matters from the point of trauma; considerably thin calvaria may lead to the fracture of the skull bone followed by subarachnoid hematoma, brain damage and it may often result in fatal consequences. Cortical skull bone thickness and its density will matter in dealing with the dynamic response of the skull towards its offering resistance against the velocity of blow and site of injury. Often calvaria thickness will stand as a weak structural entity irrespective of his/her stature and build of an individual **[15]**.

Elstic properties of the cranial vault sutures play an important role in withstanding the mechanical load of any head injury through stress distributing property. Mechanical load could be due to traffic accidents, sports injury, accidental fall, violence, etc. which results in various types of fractures of the skull bones. Collagen is an important organic connective tissue fibres existing abundantly in different tissues of the body. Which is an important mineralised scaffolding of the bone tissue which adds to the flexibility to the bone. Its complexly oven fibres are arranged helical pattern seen in periosteum and endosteal layer of outer and inner table of the cranial bones. In the diploe they are arranged in an irregular pattern. The pattern of microarchitectural arrangements of collagen fibres will influence the mechanical properties of skull bones by making the skull bone as a robust, and dynamic biological entity **[16]**. The calvaria thickness is much essential consideration from the point of neurosurgical procedures like cranioplasty. Where the surgeon will try to find a right calvaria thickness for harvesting. In this respect the right choice would be the region of calvaria which is preferably much away from the midline to avoid the site of underlying important structures like dural venous sinuses. Such autograft surgical procedure is having much encouraging results with less chance of rejection and infection **[17]**.

Gross anatomical study of pattern of diploic veins is challenging. The radiological investigations are the hallmark in the study of its density. Diploic vein pattern is highly dispersed communication; among them FDV (frontal diploic veins) are of various pattern. Understanding the density of diploic venous channel of the skull is an important anatomical information from the point of neurosurgical approach to avoid handling the bleeding prone spots and to facilitate drainage of blood. Study shown the diversified connections between the diploic veins on the skull bones with the dural cranial venous sinuses. The partial bone middle table was found with the high density of diploic venous channels, in contrast no such venous channels were noted in the temporal region **[18]**. Bones may tend to show subtle resorption changes with the advancing age irrespective of gender. Which are prone for much adverse effects especially in the females due to fluctuating hormone levels with age it is an important concern need to be studied through longitudinal follow-up study.

The present study has incorporated only potential risk age groups to signify the anatomical variation in the skull layer thickness. It is also important from the point of handling the accidental injuries or handing the part of the skull in skull grafting. In females, the diploe of the frontal region is showing considerable thickness compared with males (**Figure 2)**. The diploe layer of frontal bone exhibits a significant difference ($p < 0.004$) with females having a thicker mean of 2.40 ± 1.43 compared to males with 1.78 ± 0.91 on the left side. On the right side of the frontal region, the diploe layer exhibits a highly statistically significant disparity ($p = 0.0001$), indicating that females (2.34 ± 1.45) have a significantly thicker diploe layer compared to males (1.82 ± 0.89). Skull bone thickness when compared with the different age and gender there were no significant differences were observed between the groups. Comparing the skull bone thickness of different tables on right and left sides (**Figure 3 & 4**). The highly vascular strata that is diploe is the only versatile component showing the differences where the females will be having more advantage of having considerably thick vascular strata when compared to males. These observations were found consistent with other similar studies[10]. The outcome is indicating no significant changes neither in the cranial outer table nor in the inner table, but changes were observed only with respect to diploe, where the female gender is dominating.

Conflict of Interest: NIL

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