OS INCAE MORPHOMETRIC, CLINICAL AND MEDICOLEGAL PERSPECTIVES

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ABSTRACT
Os Incae have a definite anthropological value as an epigenetic trait in the racial differentiation. A study was undertaken to find the occurrence of Inca bones in the population of north Indian belt. Four out of 150 intact macerated skulls studied had these Inca bones in varied shapes and number. These supernumerary bones when present can alter the occipital bone appearance as a bipartite symmetrical /asymmetrical; tripartite symmetrical / asymmetrical; multipartite or with solitary /multiple Inca bones in it. A morphometric study of Inca bones included their number, shape, size, position - distance from the highest nuchal lines (HNL), the superior nuchal lines (SNL) and the parietal foramina (PF). All the Inca bones were accompanied by one or more sutural bones. Incidence of Inca bones was 2.7% in this study. Their morphogenesis was discussed. The data was compiled and compared with the earlier studies to provide a north Indian database to elaborate their significance in the Living Anatomy in the radiological, surgical and medicolegal fields.

Key words : Os Incae, morphometry, occipital bone, wormian bones, os interparietale.

INTRODUCTION
Os Incae or the Inca bones are supernumerary bones in the interparietal region. There morphogenesis depends on partial or complete failure of fusion of the ossification centres of the squamous part of the occipital bone[1]. The large number of variations seen in these bones according to Hanihara & Ishida (2001)[2] are due to various combinations, in the manner and degree of ossification of the occipital bones Various studies have shown that crania with the Inca bones mostly have wormian bones too Das et al (2005)[3]. Inca bones are of great anatomical and anthropological importance. The name os Inca (belonging to Inca Population) itself is suggestive of their ethnic correlation and hence their genetic inheritance. The additional sutures present due to these bones in skiagrams can be misinterpreted as posterior skull fractures with grave radiological, surgical and forensic implications Fujita (2002)[4]. Clinically these may be related to host of conditions like defects in ossification, metabolic disorders, due to underlying pathology of the central nervous system in hydrocephalus1 or as part of certain syndromes. The presence of additional bones is also attributed to the stress which causes cranial deformation because of environmental variations in dural strain within open sutures and fontanellae. Sanchez et al (2007)[5]. Present study presents the incidence and position of Inca bones in north Indian belt as a ready reckoner for the neurosurgeons and forensic experts.

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MATERIAL AND METHODS
The present study was conducted for the presence of Inca bones on 150 dry macerated intact skulls of unknown age and sex from the bone collections of the anatomy departments of the medical colleges of the north Indian region. These Inca bones were found in 4 skulls only. Their number; whether dividing the occipital bone in 2 (bipartite), in 3 (tripartite) or more (multipartite); the position right (dextra), left (levo) were noted. The maximum width and height of Inca bones were measured. The distance of their apices from the parietal foramen (PF), from the nearest points on the highest nuchal lines (HNL), the superior nuchal lines (SNL) and the external occipital protuberance (EOP) were measured with the vernier callipers. The apical angles subtended by them were also measured by goniometer. Very small sutural bones confirming to their position in the sutures and the bones not coinciding with the positions of ossification centres of occipital bones were not taken into consideration. The results were compiled and compared with the results of other studies to provide an Indian data base to radiologists and clinicians for reference.

OBSERVATIONS

Out of 150 specimens, four skulls presented with the Inca bones. There were associated wormian bones in all these four skulls.

Fig 1.Skull '131'- It is a levo asymmetric bipartite occipital bone. It has 'I' a triangular Inca bone on left lateral side, 6.8 cm long and 4.3cm wide. Apex is 3.8cm from the (PF); 3.6cm from (HNL) and 4.9cm from the (SNL). PF is 8.5cm from (EOP).

Fig 2. Skull '21'- It is a levo asymmetric tripartite occipital bone. It has a left lateral triangular 'Tr' Inca bone with transverse suture 7.7 cm. long and 4.2 cm from (EOP). Apical angle is 730. Central diamond shaped segment 'Qr' 7.4cm long, 8.5cm wide with apical angle 820. Lower angle is 0.7cm from the HNL and 1.9cm from the SNL. Apex is 4.5cm from the PF which itself is 8.7cm from (EOP).

Fig 3. Skull '12'- It is an asymmetric multipartite occipital bone. It has 5 multifocal interparietal bones, 2 on left side, 2 on right side near apex and another on right side a little distance away. Apex is 2.9cm from PF; 3.5cm from the HNL; 6.0cm from the SNL. PF is 7.9cm from (EOP).

Fig 4. Skull '138'- has two midline interparietals; apex of upper is at a distance of 9cm from HNL and 10.7cm from SNL; lower end of lower bone is 5.2cm from HNL and 6.9cm from SNL. Apex of upper is just 1.6cm from the right PF and of lower is 2.7cm from the left PF, lower end of lower os is 4.8cm from PF. PF is 9.8cm from (EOP). This bone has many more sutural bones.

DISCUSSION

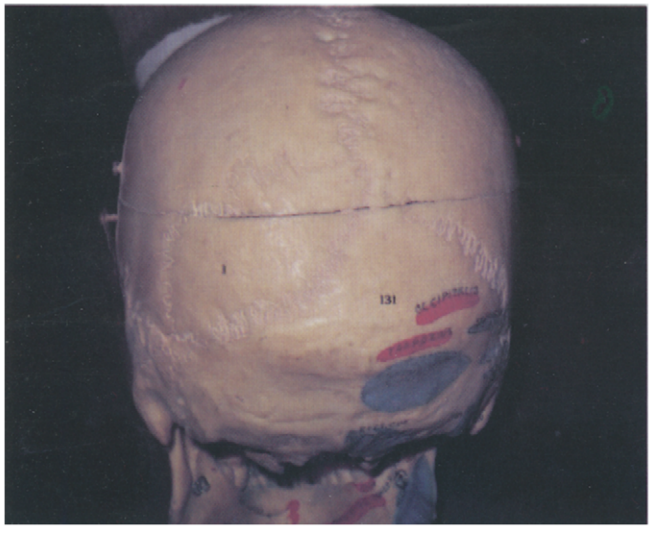

Fig 1. Skull 131- levo asymmetric bipartite occipital

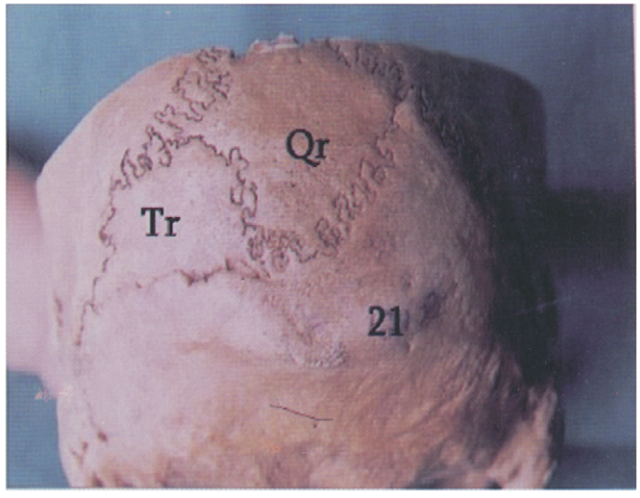

Fig 2. Skull 21- Levo asymmetric tripartite occipital

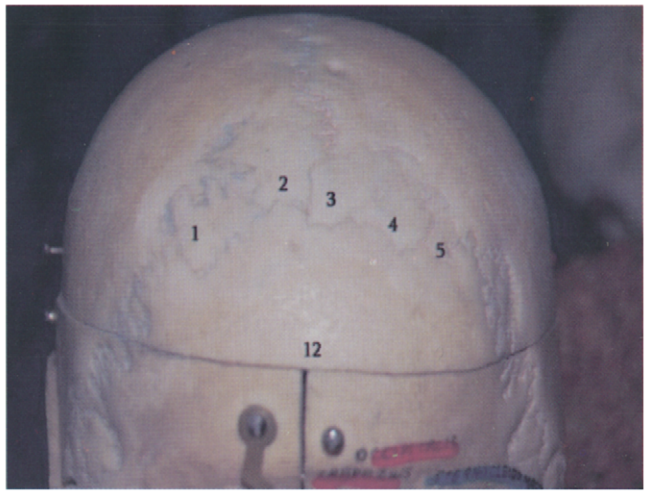

Fig 3. Skull 12- asymmetric multipartite occipital

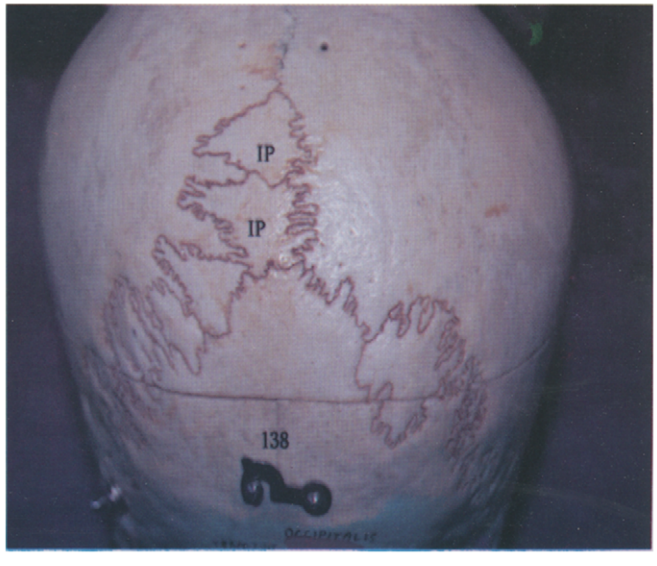

Fig 4. Skull 138- multifocal multipartite occipital

Author	Site	Number	Percentage
Srivastava (1977)[9]	India	620	0.8
Malhotra et al (1978)[19]	India	1500	0.37
Singh et al (1979)[20]	India	500	1.6
Pal et al (1984)[14]	India	348	2.6
Saxena et al (1986)[21]	Nigeria	40	2.5
Yucel et al (1998)[22]	Turkey	540	2.80
Zambare (2001)[23]	India	310	0.99
Walulkar et al (2006)[24]	India (agra)		3%
Marathe et al (2010)[6]	India (central)	380	1.3
Da Mata et al (2010)[16]	Brazil	104	1.92
Present Study (2004 - 10)	India	4/150	2.7

TABLE I. INCIDENCE OF INTERPARIETAL BONES

Though not uncommon, yet not seriously classified, the supernumerary bones in the skull have a definite morphogenetic Marathe et al (2010)[6] and morphometric significance in the living anatomy. An isolated large sized bone found at the lambda is known as the "Inca Bone" or "Goethe's ossicles"1. Inca bones are also named as interparietal bones as they lie in between the two limbs of the lambdoid suture of the parietal bones. The os Incae are the normal variants of the occipital bone as they develop due to defective ossification; partial / complete non fusion or appearance of additional ossification centres of occipital bone, in contrast to wormian bones which are due to additional ossification centres in the sutures and the fontanellae, usually most frequently found in the lambdoid suture. The squama of occipital bone has a dual origin, upper the interparietal part is a membrane bone, and the lower, supraoccipital part, a membrane cum cartilage bone, the two having different phylogenetic origin Niida (1992)[7]. So the SNL is the demarcation between the membranous and the cartilaginous parts[8]. According to Srivastava (1977,1992)[9,10], Matsumuro et al (1993, 1994)[11,12], the supraoccipital part extending between the posterior margin of the posterior condylar fossae to the highest nuchal line has two parts, the intermediate segment (between the highest and superior nuchal lines is a membranous bone and rest of the lower part is a cartilaginous bone. The membranous part of the occipital bone develops by three pairs of centres. The first pair, in which each centre consists of one nucleus, forms the area between the superior and highest nuchal lines and is known as the intermediate segment, torus occipitalis transversus or lamella triangularis. Above the intermediate segment, there is a second pair of centres, one on each side of the midline each comprising two nuclei, lateral and medial hence these four nuclei form the lateral plate of the interparietal. The third pair of centres lying near midline, each having two nuclei the upper and lower, forms the medial plate of the interparietal bone. This means that the interparietal bone is formed by the lateral and medial plates together. However the presence of another fourth pair of centres named as preinterparietals has been proposed[12]. Pal (1984)[13], Pal et al (1987)[14], state that a separate pre-interparietal bone should be defined only when it is present behind the lambda within the territory of the membranous part of the occipital bone and is separated from the remaining interparietal part by a suture. Misra (1960)[15], states that a large wormian bone is seen at the site of lambda and it has been called as epactal or epiparietal. The cartilaginous supraoccipital part develops from five centres in cartilage, two centres for each lateral segment and a single centre for the central segment. All these centres then fuse together to form a single occipital bone. Inca bones form when in the interparietal area either there is failure of fusion of the existing centres or of their nuclei with each other or an additional ossification centre develops Hanihara & Ishida (2001)[2]. Any defective fusion of these centres leads to many variations in the shape and number of these Inca bones. Normal variation in suture pattern gives the Inca bone a variable appearance which may be triangular, rectangular, diamond-shaped or M-shaped. Rarely there may be a persistent superior median fissure running vertically and dividing the bone into two giving it a bifid appearance. Occasionally it may be seen as two separate laterally placed bones. As a result of anomalous presentations the occipital bone may appear as a bipartite symmetrical /asymmetrical; tripartite symmetrical / asymmetrical; multipartite or with just a solitary

/multiple Inca bones in it. Phylogenetically while ascending the hierarchy of evolution the interparietal bone which was a part of parietal bone in ruminants, ungulates and carnivores, shifted to the occipital bone in rodents onwards to primates Da Mata et al (2010)[16].

Reviewing the skulls according to the criteria put forward by Srivastva (1993)[10], Skull '131' is a levo asymmetric bipartite occipital bone. It has type II Hanihara, Ishida, (2001)[2] Inca bone. It is formed by fusion of left upper and lower nuclei of the third pair and the left lateral nucleus of the second pair.

Skull '21' is a levo asymmetric tripartite occipital bone. Left triangular 'Tr' is formed by the left lateral nucleus of second pair. Central quadrangular 'Qr' is formed by upper and lower nuclei of both right and left centres of third pair.

Skull '12' is an asymmetric multipartite occipital bone. It has 5 multifocal interparietal bones. 1 and 5 are formed by left and right lateral nucleus of second pair; 2 by upper and lower nuclei of left third pair and 3 and 4 are formed by two nuclei of right third pair.

Skull '138' has two interparietals, apex of upper is at a distance of 9cm from HNL and inion and 10.7cm from SNL; lower end of lower bone is 5.2cm from HNL and 6.9cm from SNL. Apex of upper is just 1.6cm from the PF. The distance of these bones from HNL and SNL is significantly more than the normal distance of 4 and 5cm respectively as supra occipital part extends to about 2cm from inion9; parietal foramen is 2-5cm from lambda and 83 mm from inion Mann et al, (2009)[17], 3-5cm from and lambda1, and also their position and their close proximity to the parietal foramen, club them more accurately under preinterparietals or epiparietal bones.

The os Incae are of anatomic and anthropological importance as these bones have been named so because of their presence in abundance in mummies from the Inca civilization found in Peru. These bones can be found as normal variants and seem to be determined genetically as a racial feature of Native American Indian populations. The original description of wormian bones as a characteristic of the Inca population comes from an 1851 book "Peruvian Antiquities" by Rivero Edwards and Von Tshudi, cited by Jeanty (2005)[18]. These have been reported in varied frequency in different populations of the world.

The incidence of the interparietal bone varies among different populations. It is 15% in Nigerians, 1.2% in Europeans, 0.8% in Australians, 4.8% in North Americans, 2.4% in Indians and 2.8% in Turkish cited by Yucel et al (1998)[22], but has been reported to be as high as 27.71% in peruvian skulls Garcia et al (1956)[25]. Our results are in concurrence with some of the previous studies. The frequency distribution of os Incae is described as generally high in New World and Subsaharan Africa, Tibetan, Nepalese, Assam and Sikkim populations in northeast India and is low in north east , Central, west Asia, Europe and Australia Hanihara & Ishida (2001)2. The geographical and ethnographical pattern of incidence of Inca bones shows a definite topographical and racial predilection and thus a possible genetic inheritance. The occurrence of these Inca bones therefore has been used as one of the nonmetrical epigenetic traits in racial differentiation, in other words these may be markers of an embryological process and give us important information about human genetic architecture and perhaps more realistically, help in our understanding of the aetiology of congenital disease Berry & Berry (1967)[26].

Clinically these bones are related to many conditions like defects in ossification, metabolic disorders, underlying pathology of the central nervous system in hydrocephalus1 or as part of certain syndromes. The presence of supernumerary bones is also attributed to the mechanical stress because of environmental variations causing cranial deformation, inadvertent or may be purposeful, producing dural strain in open sutures and fontanellae[5],

These additional bones demarcated by multiple sutures can have grave radiological, neurosurgical and medicolegal implications6. Complex developmental patterns of the occipital bone and the considerable normal variation of sutures as accessory cranial sutures may simulate fractures around the foramen magnum Nakahara (2003)[27]. Though sutures have a different radiological appearance but when present at uncommon sites in occipital bone can be misinterpreted as fracture lines leading to unwarranted surgical manoeuvres. However the distinction between the Inca bone and a skull fracture is accomplished by noticing the irregular contour of the edges of the Inca bone compared with the smoother, linear course of a skull fracture but in Fig 2. the transverse suture line of the lateral segment is absolutely linear like a fracture line. The distinction is important in avoiding worries to the patient and the family experiencing an evaluation for non accidental trauma Parente (2001)[28].

Recognition of these structures and their possible variations will help in distinguishing normal from

potentially abnormal structures during computed tomography and magnetic resonance imaging examinations, and in avoiding misinterpretations that lead to confusion during surgical interventions. Instrumentation near potential bone gaps may traumatize important neural or vascular structures Keskil (2009)[29]. In forensic studies sutures simulating a fracture line and vice versa can tilt the balance from non grievous to grievous injuries.

CONCLUSION

Seemingly innocuous Inca bones occupying interparietal area have a genetic, ethnic, topographical and hence an anthropological forebearance. Leaving aside the contradictory opinions regarding their morphogenesis, these certainly are the product of partial or complete non fusion of various nuclei of the ossification centres of the occipital bone. Their radiological, surgical and medico legal significance, because of their simulation as fractures and leading to unwarranted surgeries, cannot be undermined.

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