Anatomical Science International (2019) 94:101–109
https://doi.org/10.1007/s12565-018-0454-x

ORIGINAL ARTICLE

Prevalence of wormian bones in dried adult human skulls: an osteo-morphometric study in Nepal

Laju Maya Basnet[1] · Sunara Shrestha[1] · Subash Sapkota[2]

Received: 13 February 2018 / Accepted: 7 August 2018 / Published online: 14 August 2018

Abstract
The purpose of this study was to determine the incidence of wormian bones (WBs) in different head shapes of Nepalese skulls along with their distribution at various sites. This study was conducted on 70 Nepalese skulls obtained from the Department of Anatomy, Nepal Medical College, and the Institute of Medicine from September 2017 to January 2018. The skulls were examined for the presence and topographic distribution of WBs. The occurrence of WBs at various sites was correlated among different head shapes. The incidence of skulls showing WBs was 88.57%. The WBs were observed at the lambdoid (61.43%), parietomastoid (41.43%), occipitomastoid (27.14%), pterion (25.71%), asterion (24.29%), lambda (11.43%), sagittal (7.14%) and coronal sutures (4.28%). The dominant head type was dolichocephalic (44.29%) and the least dominant was brachycephalic (10%). The maximum number of WBs was shown on brachycephalic (mean 8.86 ± 7.13) then hyperdolichocephalic (mean 8.33 ± 9.15), mesaticephalic (mean 5.10 ± 4.45) and dolichocephalic heads (mean 4.16 ± 5.30). Brachycephalic heads frequently exhibited WBs at the pterion (57.14%) and at different sutures: lambdoid (71.42%), parietomastoid (57.14%), sagittal (28.57%) and squamous (14.28%). Hyperdolichocephalic heads displayed more lambda (33.33%) and coronal (8.33%) WBs. Similarly, dolichocephalic and mesaticephalic heads showed WBs at the occipitomastoid (35.48%) and asterion (30%), respectively. Inca bones were only identified in three dolichocephalic skulls. Neurosurgeons, radiologists and orthopedists should be careful when doing clinical and surgical procedures on different head shapes of the Nepalese population.

Keywords Brachycephalic · Lambdoid · Skulls · Sutures · Wormian bones

Introduction

Wormian bones (WBs) are irregularly shaped islands of bones found within the cranial suture and fontanelles. They are derived from additional ossification centers and most commonly present in the lambdoid suture and posterior fontanelle (Standring 2016). They were named "wormian bones" after the Danish anatomist, Olaus Worm (Pryles and Khan 1979). An isolated large bone at the lambda is called as an Inca bone or Goethe's ossicle (Standring 2016). The term "Inca bone" was used because it was commonly observed in the skull of indigenous Incas (South American Indians) (Vishali et al. 2012). These WBs are also present at the pterion as pterion ossicles or epipteric bones (Standring 2016) and at the bregma as the os Kerckring (Vishali et al. 2012).

WBs can be observed in healthy individuals as a normal anatomic variant but tend to be smaller and fewer in number (Kaplan et al. 1991). However, a higher incidence of WBs has been observed in patients with certain kinds of congenital disorders (Kaplan et al. 1991) such as osteogenesis imperfecta, rickets, cleidocranial dysostosis, congenital hypothyroidism, oto-palato-digital syndrome, Down's syndrome, and so on, and children with central nervous system abnormalities (Pryles and Khan 1979) such as hydrocephalus, microcephaly, macrocephaly, craniosynostosis, cerebral palsy and epilepsy. Knowledge about WBs is essential for radiologists when interpreting skull radiographs as they may be mistaken for fractures in case of head injuries and for neurosurgeons when performing craniotomies (Patel et al. 2015; Murlimanju et al. 2011).

✉ Laju Maya Basnet
laju.basnet@gmail.com

1 Department of Anatomy, Nepal Medical College, Kathmandu University, Attarkhel, Gokarneswor Municipality-15, Post Box No. 13344, Kathmandu, Nepal

2 Department of Anatomy, Gandaki Medical College, Kathmandu University, Pokhara, Nepal

The cranial index is one of the important cephalometric indices used by anthropologists and forensic experts. It was first discovered in 1840 by the Swedish anatomist, Anders Retzius, to classify ancient human remains found in Europe. Retzius only described two terms, gentes dolicocephalae for elongated heads and gentes brachycephalae for short and broad heads (Collett and West 1993).

The prevalence of WBs in the Nepalese population has been scantly reported. This study aimed to determine the incidence of WBs in different head shapes of Nepalese skulls along with their distribution at various sites.

Materials and methods

The present study was carried out after obtaining ethical approval from the Research and Institutional Review Committee (IRC) of Nepal Medical College. It was conducted at the Department of Anatomy, Nepal Medical College, Attarkhel, and Institute of Medicine, Maharajgunj, Nepal, from September 2017 to January 2018. Ninety-eight adult human dry skulls of unknown sex with intact calvaria and erupted third molar teeth were obtained. Of these, 28 skulls were excluded because of obliteration of sutures. The skulls were examined for the presence and topographic distribution of WBs. To take cranial measurements for the cranial index, the skulls were oriented on a Frankfurt plane. The measurements were taken using a spreading caliper.

The following measurements were taken:

1. Maximum cranial length: from the glabella to opisthocranion (posterior-most point in the mid-sagittal plane of the occiput) (Anjum et al. 2016).
2. Maximum cranial breadth: between two euryons (most lateral point on the side of the head) (Anjum et al. 2016).

The cranial index was calculated using the following formula:

$$\text{Cranical index (CI)} = \frac{\text{Maximum cranical breath}}{\text{Maximum cranical length}}$$

The head shapes were classified according to the Garson (1887) classification into the following categories (Table 1).

Table 1 Classification of head shape according to the cranial index

Head shape	Cranial index range
Hyperdolichocephalic	65–69.9
Dolichocephalic	70–74.9
Mesaticephalic	75–79.9
Brachycephalic	80–84.9

Data obtained were analyzed using SPPS 16 software. The bivariate Pearson correlation test was performed to determine the correlation of the incidence of WBs on the right and left sides of skulls.

Results

Seventy skulls were studied for both the occurrence of WBs and measurement of the cranial index.

Incidence of WBs

WBs were observed in 62 (88.57%) skulls, and the remaining 8 (11.43%) skulls had no WBs. Among those 62 skulls, 54 (77.14%) had WBs on their right half and 49 (70%) on their left half.

Presence of WBs at different regions of the skull

The WBs were observed at different regions of 70 skulls and found to be most common at the lambdoid suture in 43 (61.43%) skulls: 18 unilateral and 25 bilateral (Fig. 1). The second most common site of WBs was the parietomastoid suture, found in 29 (41.43%) skulls: 21 unilateral and 8 bilateral (Fig. 2). Among those 29 skulls, the majority ($N = 21$, 30%) showed WBs at the parietal notch (Fig. 2, 3). WBs at other locations such as the occipitomastoid suture (Figs. 2, 3), pterion (Figs. 2, 4) and asterion (Fig. 5) were observed in almost equal numbers of skulls, i.e., 19 (27.14%), 18 (25.71%) and 17 (24.29%) skulls, respectively (Table 2). WBs at lambda were observed in eight (11.43%) skulls (Fig. 9). Similarly, WBs were observed at the sagittal suture in five skulls (7.14%) (Fig. 6) and

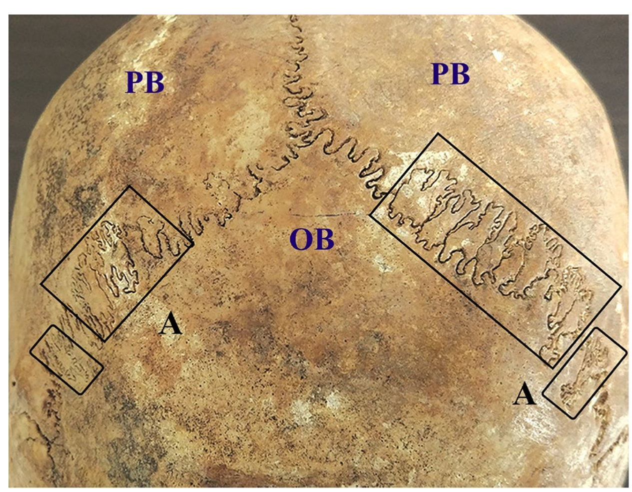

Fig. 1 A skull showing multiple wormian bones at the lamboid suture (A). *OB* occipital bone, *PB* parietal bone

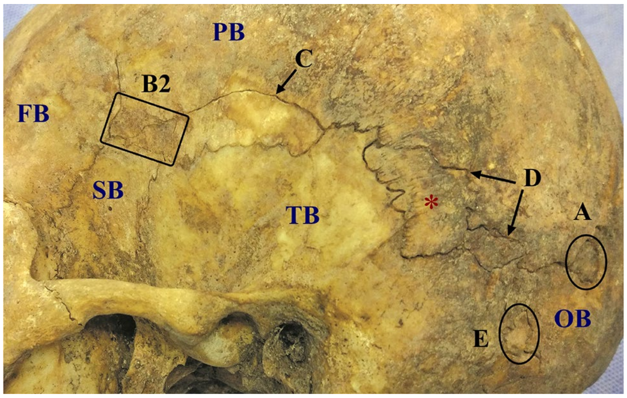

Fig. 2 A skull showing wormian bones at multiple sites. A: Wormian bone at the lambdoid suture. B2: Two wormian bones at the left pterion demarcated by a faint suture. C: Wormian bone at the left squamous suture. D: Wormian bones at the left parietomastoid suture (*wormian bones at the parietal notch). E: Wormian bone at the left occipitomastoid suture. *FB* frontal bone, *OB* occipital bone, *PB* parietal bone, *SB* sphenoid bone, *TB* temporal bone

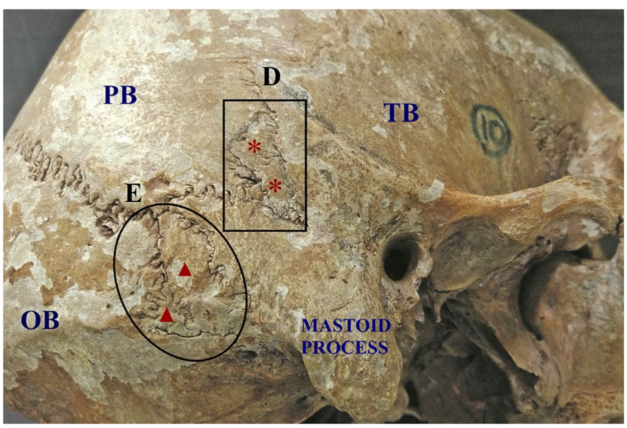

Fig. 3 A skull showing wormian bones at the left parietal notch (D, indicated by asterisk) and left occipitomastoid suture (E, indicated by triangle). *OB* occipital bone, *PB* parietal bone, *TB* temporal bone

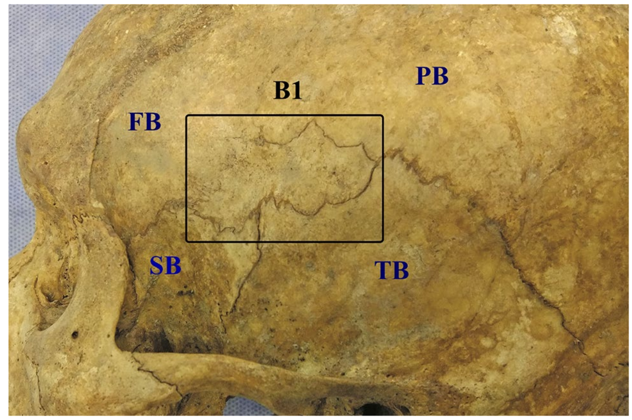

Fig. 4 A skull showing a large wormian bone at the left pterion (B1). *FB* frontal bone, *PB* parietal bone, *SB* sphenoid bone, *TB* temporal bone

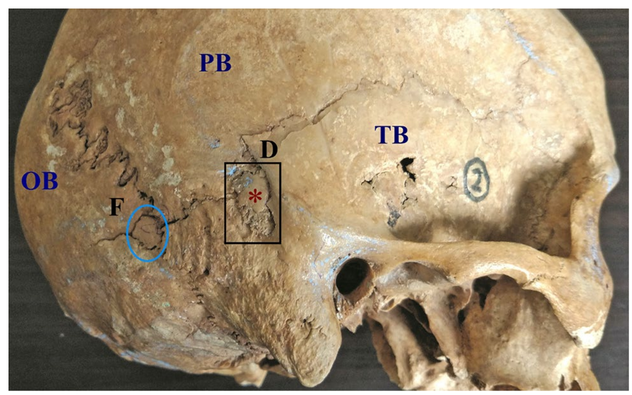

Fig. 5 A skull showing a wormian bone at the left parietal notch (D) and left asterion (F). *OB* occipital bone, *PB* parietal bone, *TB* temporal bone

coronal suture in three (4.28%) (Table 2). WBs along the coronal suture were very small, i.e., < 0.3 cm, compared with the others. None of the skulls showed WBs at the bregma. The occurrence of epipteric bones was observed unilaterally in 13 (18.57%) and bilaterally in 5 (7.14%) skulls. Of 18 skulls, only 2 showed 2 epipteric bones at the right and left pterion (Fig. 2), respectively, whereas the remaining 17 displayed a single epipteric bone (Fig. 4). There was a positive significant correlation between the right and left WBs present at the asterion and pterion as well as different sutures except the parietomastoid (Table 2).

Different head shapes

The head shape of 31 (44.29%) crania was dolichocephalic, followed by 20 (28.57%) mesaticephalic, 12 (17.14%) hyperdolichocephalic and 7 (10%) brachycephalic. None of the skulls showed hyperbrachycephalic and ultrabrachycephalic head types. In the overall crania, the most dominant head type was dolichocephalic.

Number of WBs for each head shape

While correlating WBs with different head shapes, we found the mean number of WBs in brachycephalic heads to be 8.86 ± 7.13 (range 0–20) and in hyperdolichocephalic heads to be 8.33 ± 9.15 (range 0–25). In contrast, on average fewer WBs were observed in mesaticephalic and dolichocephalic heads, where the mean was 5.10 ± 4.45 (range 0–16) and 4.16 ± 5.30 (range 0–22), respectively (Table 3). Although

Table 2 Number of skulls exhibiting WBs at different sutures and anatomic landmarks

Locations	Number of skulls showing WBs (%)	Side		*P* value
		Unilateral	Bilateral	
Lambdoid suture	43 (61.43)	Rt, 10; Lt, 8	25	0.000**
Squamous suture	5 (7.14)	Rt, 0; Lt, 3	2	0.000**
Parietomastoid suture	29 (41.43)	Rt, 11; Lt, 10	8	0.053
Occipitomastoid suture	19 (27.14)	Rt, 9; Lt, 7	3	0.039*
Coronal suture	3 (4.28)	Rt, 2; Lt, 0	1	0.036*
Asterion	17 (24.29)	Rt, 5; Lt, 7	5	0.002**
Pterion	18 (25.71)	Rt, 8; Lt, 5	5	0.018*
Bregma	0	0	0	–
Lambda	8 (11.43)	–	–	–
Sagittal suture	5 (7.14)	–	–	–

Rt right, *Lt* left

*Significant at $P < 0.05$

**Significant at $P < 0.01$

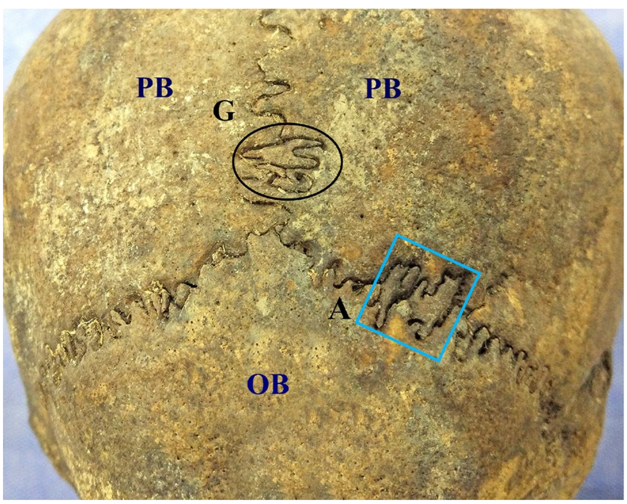

Fig. 6 A skull showing wormian bones at the sagittal (G) and right lambdoid suture (A). *OB* occipital bone, *PB* parietal bone

few brachycephalic heads were found, the incidence of a number of WBs per crania was higher in that particular head shape than in others. The dominant head type, dolichocephalic, revealed the fewest WBs per crania. Interestingly, all the skulls with different head shapes showed more WBs at the lambdoid suture than at other locations. Among the various head shapes, lambdoid WBs were more frequently present in brachycephalic heads (71.42%). In addition, brachycephalic heads also frequently exhibited WBs at the pterion (57.14%) and at different sutures such as the parietomastoid (57.14%), sagittal (28.57%) and squamous (14.28%). Similarly, the most hyperdolichocephalic heads displayed coronal (8.33%) and lambda (33.33%) WBs (Table 4). The dolichocephalic and mesaticephalic heads frequently showed occipitomastoid and asterionic WBs, respectively (Table 4). Brachycephalic heads also demonstrated more WBs per crania at most sites.

Incidence of Inca bones

Inca bones were only observed in three (4.28%) skulls, but their number varied from one skull to another, ranging from one to three (Figs. 7, 8, 9). In one of the three, an incomplete lateral asymmetric Inca bone was present at the lambda along the left lambdoid suture (Fig. 7). Another skull showed the presence of complete asymmetric bipartite Inca bones of unequal size, the right and left being small and large, respectively (Fig. 8), while the

Table 3 Incidence of WBs in each head shape with their mean number

Head shape	Number of skulls		Mean number of WBs ± SD	Range of WBs				
	Presence of WBs	Absence of WBs		1–5	5–10	10–15	15–20	20–25
Hyperdolichocephalic	11	1	8.33 ± 9.15	5	3	0	0	3
Dolichocephalic	27	4	4.16 ± 5.30	17	8	0	0	2
Mesaticephalic	18	2	5.10 ± 4.45	9	5	3	1	0
Brachycephalic	6	1	8.86 ± 7.13	2	0	3	0	1
Total	62	8	5.61 ± 6.23	33	16	6	1	6

Table 4 Number of skulls showing wormian bones at different sites for each head shape

Head shape		Wormian bones at different sites									
		LS	SqS	PM	OM	CS	Asterion	Pterion	Bregma	Lambda	SS
Hyperdolichocephalic	*N* (%)	8 (66.66)	0	5 (41.67)	1 (8.33)	1 **(8.33)**	3 (25)	5 (41.67)	0	4 **(33.33)**	1 (8.33)
	R	(0–20)	0	(0–3)	(0–4)	(0–3)	(0–5)	(0–2)	0	(0–4)	(0–3)
Dolichocephalic	N (%)	18 (58.06)	2 (6.45)	8 (25.81)	11 **(35.48)**	1 (3.22)	6 (19.35)	5 (16.13)	0	2 (6.45)	1 (3.22)
	R	(0–18)	(0–1)	(0–3)	(0–2)	(0–2)	(0–4)	(0–2)	0	(0–2)	(0–4)
Mesati- cephalic	N (%)	12 (60)	2 (10)	11 (55)	5 (25)	1 (5)	6 **(30)**	4 (20)	0	1 (5)	1 (5)
	R	(0–12)	(0–3)	(0–2)	(0–1)	(0–3)	(0–3)	(0–1)	0	(0–1)	(0–1)
Brachy- cephalic	N (%)	5 **(71.42)**	1 **(14.28)**	4 **(57.14)**	2 (28.57)	0	2 (28.57)	4 **(57.14)**	0	1 (14.28)	2 **(28.57)**
	R	(0–11)	(0–2)	(0–4)	(0–2)	0	(0–1)	(0–2)	0	(0–1)	(0–2)

Figures in bold represent the highest percentage of crania showing WBs among different head shapes

CS coronal suture, *LS* lambdoid suture, *N* number of skulls with wormian bones, *OM* occipitomastoid suture, *PM* parietomastoid suture, *R* range of wormian bones, *SS* sagittal suture, *SqS* squamous suture

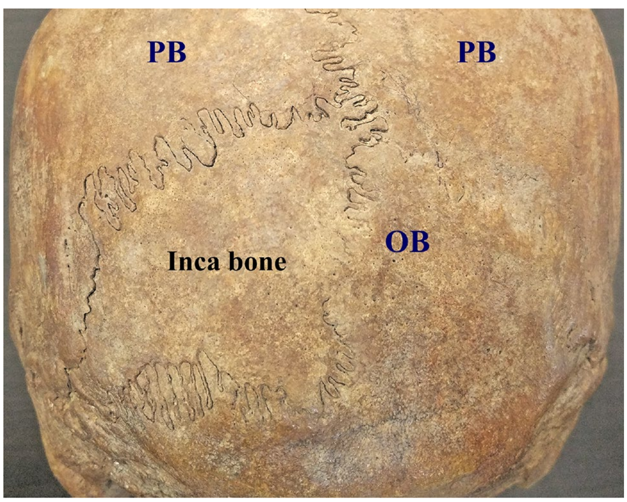

Fig. 7 Incomplete lateral asymmetric Inca bone. *OB* occipital bone, *PB* parietal bone

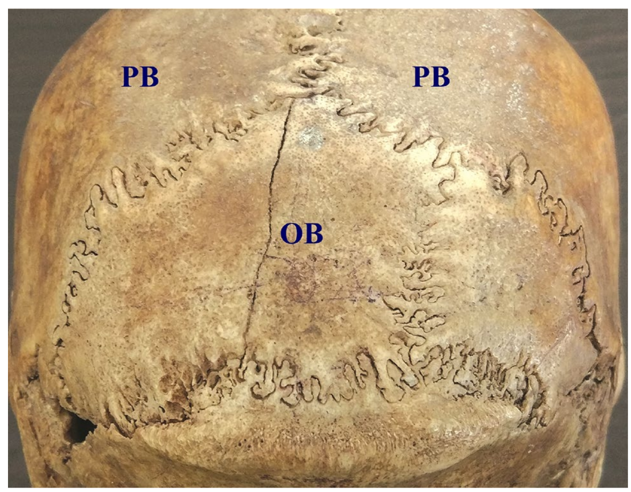

Fig. 8 Complete asymmetric bipartite Inca bone. *OB* occipital bone, *PB* parietal bone

third skull revealed a complete tripartite Inca bone with the sections demarcated from each other by well-defined sutures (Fig. 9). All three skulls showing Inca bones had a dolichocephalic head shape.

Discussion

WBs are observed as normal variants but their number and locations in skulls exhibit population-based variations (Brothwell 1963; Gümüsburun et al. 1997; Khan et al. 2011; Cirpan et al. 2015).

Incidence of WBs

In the present study, WBs were found in 62 (88.57%) of 70 dry skulls, which is comparatively higher than the findings mentioned by Brothwell (1963), who studied the prevalence of WBs in different populations, and other authors (Murlimanju et al. 2011; Khan et al. 2011; Cirpan et al. 2015; Shantharam and Manjunath 2017) (Table 5). This study also revealed the higher occurrence of WBs on the right (77.14%) than left half (70%) of skulls. In contrast, other authors (Patel et al. 2015; Kumar et al. 2016) reported more WBs on the left half of skulls in various regions of India. Some researchers inferred that WBs arise as a result of pressure across sutures exerted from external factors such as

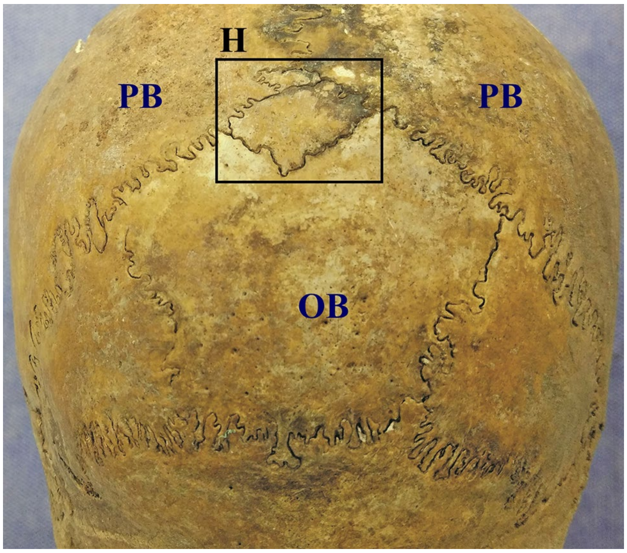

Fig. 9 Complete tripartite Inca bone and wormian bones at lambda (H). *OB* occipital bone, *PB* parietal bone

Table 5 Comparison of incidences of wormian bones in different populations

Population	Incidence (%)
Chinese[a]	80.32
German[a]	75
Australian[a]	72.58
Iron Age/Romano-British[a]	71.03
Melanesian[a]	64.15
Lachish[a]	63.41
Anglo-Saxon[a]	55.56
Malaysians (Khan et al. 2011)	24
Coastal South Indians (Murlimanju et al. 2011)	73.1
West Anatolian (Cirpan et al. 2015)	59.3
Gujarati (Patel et al. 2015)	44.4
Central Indians (Kumar et al. 2016)	32
South Indians (Shantharam and Manjunath 2017)	81.89
Nepalese (Eastern Nepal) (Sah et al. 2017)	68.75
Nepalese (Central Nepal), present study	88.57

[a]According to Brothwell (1963)

artificial cranial deformation (Bennett 1965; Sanchez-Lara et al. 2007). However, Berry and Berry (1967) and Hanihara and Ishida (2001a) proposed genetic factors as one of the causes for the development of WBs. In our study, crania of Central Nepal (Kathmandu) showed a higher frequency of WBs, possibly because this region consists of various ethnic groups that migrated from Tibet and the Himalayas. A higher incidence was found in Tibetan/Nepalese samples (Hanihara and Ishida 2001a). However, an article from Eastern Nepal (Sah et al. 2017), which includes more people of Indian origin, revealed a comparatively lower frequency of WBs. Thus, it is possible that the higher incidence of WBs in the present study may be due to variable genetic predispositions among different races.

Presence of WBs at different regions of the skull

In our study, the lambdoid suture was the most common site for the occurrence of WBs, which concurs with the findings of other authors (Murlimanju et al. 2011; Gümüsburun et al. 1997; Shantharam and Manjunath 2017; Sah et al. 2017) (Table 6). WBs were more frequently observed at the lambdoid suture in 61.43% skulls. A similar finding was observed in Turkish (Gümüsburun et al. 1997) and Eastern Nepalese (Sah et al. 2017) skulls, but this conflicts with other studies conducted on Indian skulls (Patel et al. 2015; Showri and Suma 2016), where a lower incidence of lambdoid WBs was observed (Table 6). The second most common site of WBs in our study was the parietomastoid suture (41.43%), which differs from other studies conducted on Turkish (Gümüsburun et al. 1997) and Indian (Patel et al. 2015; Murlimanju et al. 2011; Shantharam and Manjunath 2017) skulls, where they observed it to be the asterion. WBs were observed at the parietal notch in 30% of our skulls, which is higher than the incidence observed in Turkish (Gümüsburun et al. 1997) and Malaysian (Khan et al. 2011) skulls but lower than that in South Indian (Shantharam and Manjunath 2017) skulls (Table 6). This study showed a higher incidence of WBs at the occipitomastoid (27.14%), asterion (24.29%) and lambda (11.43%) compared with Turkish (Gümüsburun et al. 1997), Malaysian (Khan et al. 2011) and Indian (Patel et al. 2015; Kumar et al. 2016) skulls (Table 6). In contrast, Shantharam and Manjunath (2017) observed more WBs at the asterion and lambda in South Indian crania. The lowest frequency of WBs was observed at three different sites (sagittal, squamous and coronal suture). The incidence of sagittal (7.14%) and coronal (4.28%) WBs in our study was higher than the findings reported in Turkish (Gümüsburun et al. 1997) and Coastal South Indian (Murlimanju et al. 2011) skulls. In addition, some of the studies conducted in Indian skulls showed the absence of WBs at the sagittal suture (Patel et al. 2015; Kumar et al. 2016) (Table 6).

Epipteric bone was observed in 25.71%, which is higher than the findings of various authors in different populations (Murlimanju et al. 2011; Gümüsburun et al. 1997; Sah et al. 2017) (Table 6). Research carried out in different parts of India even showed a lower incidence of epipteric bones ranging from 0.03 to 2% (Patel et al. 2015; Kumar et al. 2016; Showri and Suma 2016) (Table 6). In our study, even a bilateral occurrence of epipteric bone was observed. However, Murlimanju et al. (2011) and Sreekanth (2017) only noted the unilateral occurrence of epipteric bones. Our study also showed the presence of two epipteric bones in

Table 6 Incidence of wormian bones at different regions of skulls among various populations

Population	*N*	Number of skulls showing wormian bones at different regions in %									
		LS	SqS	PM	OM	CS	Asterion	Pterion	Bregma	Lambda	SS
Turkish (Gümüsburun et al. 1997)	302	61.89	–	PN-7.92	0.99	2.97	15.20	9.92	0.66	10.9	1.65
Malaysian (Khan et al. 2011)	25	4	4	PN-4	4	8	0	0	0	8	8
Coastal South Indian (Murlimanju et al. 2011)	78	56.4	–	–	–	1.3	17.9	11.5	0	–	1.3
Gujarati (Patel et al. 2015)	27	48.14	–	–	0.03	0.03	18.5	0.03	–	0.07	0
South Indian (Showri and Suma 2016)	132	45.45	2.27	8.33	2.27	6.06	5.30	1.51	0	13.63	4.54
Central Indian (Kumar et al. 2016)	50	44	–	–	6	–	6	2	0	6	0
South Indian (Shantharam and Manjunath 2017)	110	48.18	–	PN-35.45	13.64	10	38.18	20.91	0	22.73	3.64
Nepalese (Eastern Nepal) (Sah et al. 2017)	80	63.63	–	–	–	0	20	12.72	0	–	3.63
Present study	70	61.43	7.14	41.43 PN-30	27.14	4.28	24.29	25.71	0	11.43	7.14

CS coronal suture, *LS* lambdoid suture, *OM* occipitomastoid suture, *PM* parietomastoid suture, *PN* parietal notch, *SS* sagittal suture, *SqS* squamous suture

two skulls. Similarly, the unilateral presence of two epipteric bones in an Indian skull was reported by Sreekanth (2017). Neurosurgeons need to be aware of epipteric bones as their presence leads to complications when making burr holes during the excision of intracranial tumors (Ersoy et al. 2003). In our study, no WBs were observed at the bregma. Various authors reported similar findings in different populations (Murlimanju et al. 2011; Khan et al. 2011; Kumar et al. 2016; Sah et al. 2017) (Table 6). However, few occurrences of bregmatic bone (0.66%, 2%) were observed by some authors (Gümüsburun et al. 1997; Cirpan et al. 2015). Our study showed an interesting significant correlation between right and left WBs present at different sutures except the parietomastoid. However, the study conducted in a Turkish population (Cirpan et al. 2015) only found a fairly significant relationship between WBs at the right and left squamous suture ($P = 0.04$).

Presence of the Inca bone

In our study, the incidence of Inca bones was 4.28%, which is almost same as that of Japanese/East Asian (Fujita et al. 2002) (4.92%) and Malaysian/Southeast Asian (Khan et al. 2011) skulls (4%), but a lower incidence was observed in Turkish/West Asian (Cirpan et al. 2014) (1.98%) and Australian (Hanihara and Ishida 2001b) skulls ($\leq 1\%$). Similarly, fewer occurrences of Inca bones were reported in Indian skulls, varying from 0.3 to 2.7% (Malhotra et al. 1978; Marathe et al. 2010; Dharwal 2011). Hanihara and Ishida (2001b) studied the geographic and ethnographic variation in the frequency of the Inca bones in different populations and observed a higher incidence of Inca bones in Tibetan/Nepalese, Assam/Sikkim, East Asian and Sub-saharan African populations. In contrast, the frequencies were lower in European, Australian, Central and West Asian samples, suggesting possible genetic causes behind this global variation in the frequency of Inca bones.

We observed complete asymmetric bipartite and complete tripartite Inca bones similar to the case reported by Fujita et al. (2002). The authors concluded that the presence of Inca bones can be used in personal identification by comparing the ante- and post-mortem radiographs (Fujita et al. 2002). Inca bones are formed because of a defect in the fusion of secondary ossification centers of the squamous part of the occipital bone (Bellamy and cited in Kadanoff and Mutafov 1964).

Different head shapes

According to our study, the dominant head shape was dolichocephalic, which was observed in 44.29%. Contrarily, Lobo et al. (2005) found brachycephalic (38.2%) to be the dominant head shape in the Gurung community of Nepal. Some authors have described mesaticephalic as the dominant head shape in South Punjabi (Anjum et al. 2016), Indian (Kumar and Nagar 2015) and Nigerian (Akinbami 2014) skulls. Our study did not show any hyperbrachycephalic heads. In contrast to our observation, hyperbrachycephalic heads were observed in South Punjabi (Anjum et al. 2016) (5.1%), North Indian (Kumar and Nagar 2015) (2.5%) and Nigerian (Akinbami 2014) (0.43%) skulls. The head shape may vary among various geographic and ethnic groups. As our research was conducted in Kathmandu, an ethnically and culturally diverse city, the examined dry skulls might be from different ethnic groups. Thus, this alteration in the dominant head shape in the Nepalese population between known (Gurung) and unknown ethnic groups in our study may be correlated with a hereditary factor.

Number of WBs for each head shape

In this study, lambdoid and sagittal WBs were more frequently present in brachycephalic heads. A similar finding was observed in Turkish skulls (Gümüsburun et al. 1997). Epipteric and asterionic WBs were commonly observed in our brachycephalic and mesaticephalic heads, respectively. However, a different result was obtained in Turkish skulls (Gümüsburun et al. 1997), where epipteric was mostly seen in mesaticephalic and asterionic WBs in brachycephalic heads. Similarly, the maximum number of hyperdolichocephalic heads in our study displayed coronal (8.33%) and lambda (33.33%) WBs, but these WBs were frequently observed in dolichocephalic head shapes of Turkish skulls (Gümüsburun et al. 1997). This difference may have occurred because the author used a cephalic index < 75 for dolichocephalic heads, which also includes all hyperdolichocephalic heads. In our case, none of the head shapes showed the presence of bregmatic bones, whereas Turkish skulls (Gümüsburun et al. 1997) showed them in mesaticephalic (0.88%) and brachycephalic (0.70%) heads. The different head shapes in our study presented more WBs at different sites compared with Turkish skulls (Gümüsburun et al. 1997). The mean number of WBs was high in brachycephalic heads. Excluding hyperdolichocephalic heads, we observed an increasing pattern of occurrence of WBs per crania from dolichocephalic to brachycephalic heads. Sanchez-Lara et al. hypothesized the number of wormian bones directly correlates with more severe occipital flattening (Sanchez-Lara et al. 2007). This may be a reason behind the increasing number of WBs in brachycephalic heads.

Future perspectives

The number of WBs observed at different sites on brachycephalic heads may alter with a large sample size. Hence, more brachycephalic heads need to be studied for further confirmation. Further studies of the cephalic index in different ethnic groups in the Nepalese population are needed to ascertain the role of genetic factors in determining different head shapes among races.

Conclusions

The current study reports the higher incidence of WBs (88.57%) in Nepalese skulls compared with other populations. Similarly, most brachycephalic heads showed WBs at most sites of the crania. Radiologists, orthopedists and neurosurgeons need to be careful when performing different clinical procedures such as burr hole, craniotomies, radiologic studies, etc., particularly in brachycephalic heads.

Acknowledgements The authors express their sincere thanks to Prof. Dr. Samit Kumar Ghosh and Prof. Dr. Shaligram Dhungel, Department of Anatomy, Nepal Medical College, for their valuable advice and guidance. We also extend our gratitude to Dr. Nirju Ranjit, Head of the Department of Anatomy, Institute of Medicine, Maharajgunj, for granting us an access to dry skulls available in the department. We appreciate Mr. Prem Panta, Lecturer, Department of Community Medicine, for his support in statistical analysis.

Compliance with ethical standards

Conflict of interest None.

Ethical approval This study was approved by Research and Institutional Review Committee (IRC) of Nepal Medical College and Teaching Hospital.

References

Akinbami BO (2014) Measurement of cephalic indices in older children and adolescents of a Nigerian population. Biomed Res Int 2014:1–5. https://doi.org/10.1155/2014/527473
Anjum MI, Kanwal S, Anjum MI (2016) A craniometric study of adult dry skulls in South Punjab. Pak J Med Health Sci 10:244–246
Bellamy CF, Kadanoff D, Mutafov S (1964) Os incae bei bulgaren. Morphol Jahrb 105:602–615
Bennett KA (1965) The etiology and genetics of wormian bones. Am J Phys Anthropol 23:255–260. https://doi.org/10.1002/ajpa.1330230313
Berry AC, Berry RJ (1967) Epigenetic variation in the human cranium. J Anat 101:361–379
Brothwell DR (1963) Digging up bones. British Museum of Natural History, London
Cirpan S, Aksu F, Mas N (2014) Inca bone in human skulls of the west Anatolian populatıon. Int J Morphol 32:275–278
Cirpan S, Aksu F, Mas N (2015) The incidence and topographic distribution of sutures including wormian bones in human skulls. J Craniofac Surg 26:1687–1690. https://doi.org/10.1097/SCS.0000000000001933
Collett AR, West VC (1993) Terminology of facial morphology in the vertical dimension. Aust Dent J 38:204–209. https://doi.org/10.1111/j.1834-7819.1993.tb03065.x
Dharwal K (2011) Os incae morphometric, clinical and medicolegal perspectives. J Anat Soc India 60:218–223
Ersoy M, Evliyaoglu C, Bozkurt MC, Konuskan B, Tekdemir I, Keskil IS (2003) Epipteric bones in the pterion may be a surgical pitfall. Min Invasive Neurosurg 46:363–365. https://doi.org/10.1055/s-2003-812434
Fujita MQ, Taniguchi M, Zhu BL (2002) Inca bone in forensic autopsy: a report of two cases with a review of the literature. Leg Med 4:197–201. https://doi.org/10.1016/S1344-6223(02)00029-9
Garson JG (1887) The international agreement on the classification and nomenclature of the cephalic index. J R Anthropol Inst 16:17–20
Gümüsburun E, Sevim A, Katkici U, Adiguzel E, Gulec E (1997) A study of sutural bones in Anatolian-Ottoman skulls. Int J Anthropol 12:43–48. https://doi.org/10.1007/BF02447895
Hanihara T, Ishida H (2001a) Frequency variations of discrete cranial traits in major human populations. I. Supernumerary ossicle variations. J Anat 198:689–706

Hanihara T, Ishida H (2001b) Os incae: variation in frequency in major human population groups. J Anat 198:137–152

Kaplan SB, Kemp SS, Oh KS (1991) Radiographic manifestations of congenital anomalies of the skull. Radiol Clin North Am 29:195–218

Khan AA, Asari MA, Hassan A (2011) Unusual presence of wormian (sutural) bones in human skulls. Folia Morphol 70:291–294

Kumar A, Nagar M (2015) Morphometric estimation of cephalic index in North Indian population: craniometrics study. IJSR 4:1976–1982

Kumar TMV, Kumar V, Yadav N (2016) The occurrence of wormian bones within the cranial sutures and their clinical significance. Int J Anat Res 4:3082–3086. https://doi.org/10.16965/ijar.2016.408

Lobo SW, Chandrashekhar TS, Kumar S (2005) Cephalic index of Gurung community of Nepal—an anthropometric study. Kathmandu Univ Med J 3:263–265

Malhotra VK, Tewari PS, Pandey SN, Tewari SP (1978) Interparietal bone. Acta Anat 101:94–96

Marathe RR, Yogesh AS, Pandit SV, Joshi M, Trivedi GN (2010) Inca–interparietal bones in neurocranium of human skulls in central India. J Neurosci Rural Pract 1:14–16. https://doi.org/10.4103/0976-3147.63094

Murlimanju BV, Prabhu LV, Ashraf CM, Kumar CG, Rai R, Maheshwari C (2011) Morphological and topographical study of wormian bones in cadaver dry skulls. J Morphol Sci 28:176–179

Patel D, Chauhan K, Patil D (2015) Morphological study of wormian bones in dried human skulls. NJMR 5:222–225

Pryles CV, Khan AJ (1979) Wormian bones. A marker of CNS abnormality? Am J Dis Child 133:380–382

Sah SK, Chaudhary D, Pandey N (2017) Study of metopism and wormian bones in dry skulls of human cadavers in Nepal. Int J Anat Res 5:3443–3446. https://doi.org/10.16965/ijar.2016.499

Sanchez-Lara PA, Graham JM Jr, Hing AV, Lee J, Cunningham M (2007) The morphogenesis of wormian bones: a study of craniosynostosis and purposeful cranial deformation. Am J Med Genet A 143A:3243–3251. https://doi.org/10.1002/ajmg.a.32073

Shantharam V, Manjunath KY (2017) Occurrence of sutural bones in adult human skulls. NJBMS 7:201–208

Showri R, Suma MP (2016) Study of wormian bones in adult human skulls. IOSR JDMS 15:54–60. https://doi.org/10.9790/0853-1512055460

Sreekanth T (2017) Incidence of epipteric bones: an anatomical study with clinical implications. Int J Anat Res 5:3329–3332. https://doi.org/10.16965/ijar.2016.464

Standring S (2016) External skull. In: Black S (ed) Gray's anatomy: the anatomical basis of clinical practice. Elesvier, Philadelphia, pp 416–425

Vishali N, Ebenraj TJ, Rojomon TC (2012) A rare existence of significant number of wormian bones in the lambdoid suture. IJSR 3:671–677