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Roopkund Human Skeletal Remains: A Short Note on the Signs of Nutritional Stress and Anemia on the Cranial and Orbital Surface

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Abstract: Roopkund Lake in Uttarakhand, India, is famous for its human skeletal remains. The present paper is an attempt to investigate the relationship between porotic pathology and the health status of the Roopkund victims. The skeletal material, including the skull, vault, and other significant cranial bones, totaling 27 samples, was personally retrieved from the lake site over the course of six visits between the years of 2004 and 2007. All the skeletal remains that were obtained have been evaluated using pathological and osteological methods. The severity of the pathological findings is determined by the grading scale for the specific issue, and all discovered porotic skull pathologies fall into the categories of porotic hyperostosis and cribra orbitalia. In the discussion and final comment on the health status of the victims in the conclusion part, all identified problems and the anticipated cause or causes of the problem are reviewed and described.

Introduction

Roopkund is a small but lovely glacier lake that is 5029 metres above sea level and is located in the Chamoli district of Uttarakhand, India (Figs. 1-2). From the north-eastern side, the lake is encircled by the stunning peaks of Nanda Ghungti and Trishul Massif. Even the last settlement in the valley, Wan, is about 30 kilometres from the lake and requires three days of walking to get to the base camp because the area is desolate. The local weather is extremely sensitive and changes with height. In a given year, the lake is covered in snow for roughly ten months (Fig. 3). Only the months of August and September are suitable for tourist trips. During this period, it is common to witness numerous uncommon Himalayan flowers, including *Saussurea obvallata*, *Saussurea*

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Fig. 1: Map showing the location of Roopkund Lake

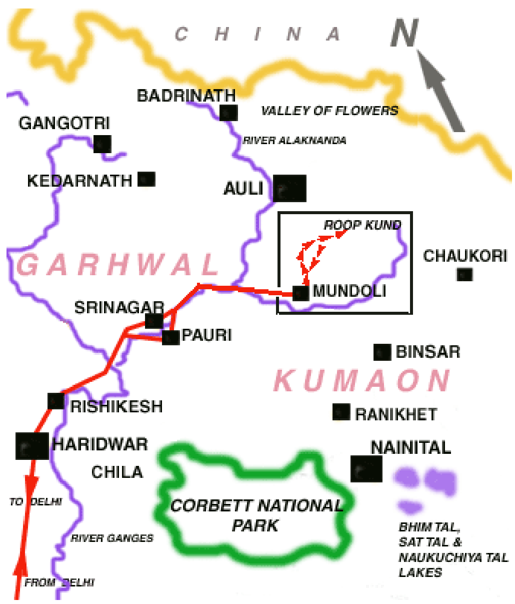

Fig. 2: Route map of Roopkund Lake

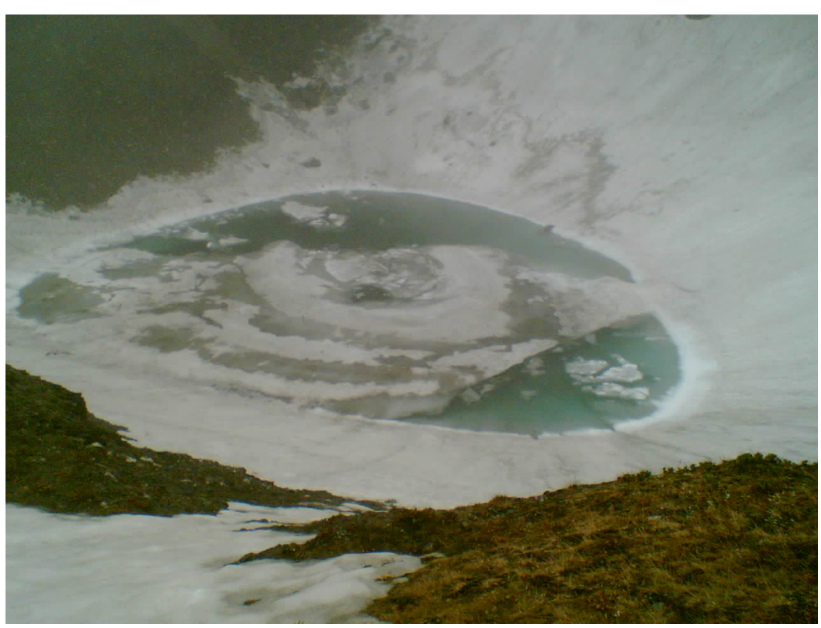

Fig. 3: General view of Roopkund Lake

simpsoniana, *Saussurea piptathera*, *Saussurea gossypiphora*, *Cryptogramma crispa* and many more. Roopkund is revered by the locals as a place of worship, and it was formerly known as 'Rudrakund' until being given the nicknames 'Mystery Lake' and 'Skeletal Lake' by visitors and researchers after the discovery of human skeletal remains there in 1942.

In 1898, a British investigator first became aware of this glacier lake (Benjwal and Hatwal 2000). On June, 1907, T.G. Longstuff, a British doctor, soldier, mountaineer, and veteran of numerous exploratory expeditions to Tibet and the Himalaya, saw these skeleton remains in the Roopkund Lake while climbing Trishul's main peak (Verma 1959). However, it was not until a 1942–1943 assignment for the gathering of some Himalayan flowers that the presence of numerous human remains on the Rupkund Lake shoreline was first acknowledged officially. On September 2, 1942, H.K. Madhwal, a forest officer, was the first official to discover a considerable number of human remains on the lake shore. The racial and historical examination of the Roopkund ruins began after Madhwal returned to the site in 1955 with Mr. Jagmohan Singh Negi, a former forest minister of the State (Madhwal 1956).

Nobody at the time knew why or how these folks had come to be here, or what had become of them. Numerous expeditions and investigations into the identities, origins, and causes of this mass casualty have been carried out since the discovery of these remains by various national institutions, but none of them have been able to definitively explain why these mysterious remains are present at this lovely Himalayan Lake. Between September 4 and September 18, 1956, three different expeditions were organised and successful in reaching Rupkund: one by the Department of Anthropology (now Anthropological Survey of India), Government of India, Calcutta, led by its Director, Dr. N. Dutta Majumdar (Negi 2009); another by the Department of Anthropology, Lucknow University, led by Prof. D.N. Majumdar (Majumdar et al. 1955, cited in Verma 1959; Negi 2009); and the third by Swami Pranavanand, Fellow of the Indian Institute of Science (Swami 1959, cited in Sax 1991). All three expeditions were successful in returning significant collections of both skeletal remains and cultural artefacts for scientific research to determine the identity and provenance of victims, as well as the timing of the tragedy (Negi 1958, 1997, 2009; also see Nautiyal et al. 1999).

These remains are the subject of numerous legends, which we might categorise as either religious or historical beliefs or scientific for our convenience. The religious beliefs associate these Roopkund remains with the Kannoj king Yasdhawal, Queen Balampa and their attendants (Swami 1959, cited in Sax 1991). Even though there is no written documentation of the Roopkund mystery, some people have done study to situate it in the historic era. For instance, these remains are those of a local epidemic victim, self-sacrificing soldiers, and self-suicidal soldiers (for details, see Negi 1997). But these are only regarded as assumptions in the absence of any written evidence. But without any written evidence these are considered only assumption. Important scientific investigations undertaken so far include osteometric analysis of bones, carbon dating and A-B-O blood group investigation. The Radio-Carbon dating from the skeletal material done by Michigan State University yielded the date as 650±150 years (Crane and Griffin 1958). National Geographic channel also conducted a scientific expedition in this lake in 2004 (National Geographic 2004). For 38 skeletons from Roopkund Lake, Harney et al. (2019) recently released genome-wide ancient DNA results. Twenty three individuals were found to have ancestry that is similar to that of contemporary South

Asians, according to their study. Fourteen people are of eastern Mediterranean descent, and one person with Southeast Asian descent is also named by them.

Objectives

The main objective of the present study was to describe the demographic profile and identify the pathological features of the remains. The study's other major goal was to identify the serious health issues and probable causes behind the majority of deaths by categorising the identified pathologies according to respective cause and causes.

Preservation and Taphonomy

The high altitude and glacial topography of Roopkund Lake have preserved all the skeletal remains with skin (Fig. 4). However, landslides have frequently broken them and scattered them throughout the valley. Some bones revealed discolouration due to sunlight exposure. Roopkund has the remains of approximately 200 individuals. But it is very hard to calculate the exact number and work on the whole assemblage. The skull remains (cranium, vault) were highly damaged and present in the form of large and small fragments. The present study included only one complete skull.

Material and Methodology

For this study, all the skeletal material has been personally collected from the site through more than six visits during the years 2004–2007. Because of the site's geographical toughness and ecological sensitivity, the only option for collecting skeletal remains was surface material. The random collection method has been used primarily for the collection of remains. The skeletal assemblage has a total of 27 skull samples,

Fig. 4: Scattered human remains on the slope of Roopkund Lake

including complete skull, cranial vaults, and small skull fragments. The selection of the samples was also not less than a puzzle for the researchers because, due to the continuous landslide and human intervention, all the remains were scattered and mixed together. Therefore, it was difficult to say whether the remains found together belong to the same individual or another.

After collection and bringing them to the Anthropology Laboratory, HNB Garhwal University, collected specimens have been cleaned with normal water and dried up in the shade. During the time of collection, skeletal fragments of different individuals got collected together as skeletal remains were scattered and mixed. Therefore, it was important to separate the bones of different individuals first. Then, with the help of adhesive, all related fragments were joined with the associated skull or bone. Skeletal remains were then subjected to careful laboratory analysis. The analysis was conducted at the Anthropology Laboratory of Deccan College, Post-Graduate and Research Institute, Pune. Craniometric observations were possible for only few specimens. Craniometric observations were recorded using the method given by Martin and Saller (1957) with the help of a spreading calliper and a sliding caliper. All measurements were recorded in millimeters. There were instances when exact measurements could not be taken, and in such cases, the measurements were recorded within brackets to indicate that they were estimates. These measurements have been listed in Table 1.

Fundamental procedures and non-metric analysis are primarily used to comprehend the Roopkund's victims' personal information and health status. To create the demographic profile of the Roopkund remains, estimates for age and sex have also been obtained. Most of the skull's remains did not have any facial portion, so the cranial suture closure method has been used for the individual's age estimation (for details on the method, see Olivier 1969; Stewart 1979; Brothwell 1981; Buikstra and Ubelaker 1994; Bass 1995). However, as we know, the suture closure rate varies from person to person and affects the age estimation. To address this issue, researchers examined sutural closure rate, texture/morphology, and robustness, as well as the fusion of the basi-occipital to the basi-sphenoid and the extension of the sphenoid sinus into the occipital bone. An estimated age has been classified into three categories: young adult (20–34 years), middle-aged adult (35–49 years), and old adult (50+ years). In addition to these categories, a new one called "adult" has been created for individuals who could not be assigned to any of the three above. Individuals' sexes were determined using non-metric observation methods and parameters proposed for skull features by Brothwell (1981), Olivier (1969), Stewart (1979), and Buikstra and Ubelaker (1994). Features such as the nuchal crest, mastoid process, supra-orbital margin, prominence of the glabella, slope of the forehead, and prominence of the temporal line have been examined for the sex determination of the remains.

Paleopathology deals with the skeletal pathologies and anomalies in the light of ecology, environmental changes, subsistence patterns, and social organization, giving a bio-cultural perspective. For this study, a pathological examination has been conducted to observe an individual's health status under the guidelines of Buikstra and Ubelaker (1994) and the GHP (Global Health Project). The pathological findings are graded according to the international grading system for the problem. Observed pathologies are categorised as follows:

Table 1: Facial and Cranial Measurements (in mm) of Roopkund Remains

S.No.	Measurement	Sp. I	Sp. II	Sp. III	Sp. IV	Sp. V	Sp. VI	Sp. VII	Sp. VIII
1	Maximum cranial length (1)	176	176	-	-	-	-	-	-
2	Glabella inion length (2)	172	170	-	-	-	-	-	-
3	Nasion inion length (2a)	164	166	-	-	-	-	-	-
4	Glabella lambda length (3)	171	171	165	158	-	-	-	-
5	Nasion basion length (5)	90	96	-	-	-	-	-	-
6	Nasion opisthion length (5-1)	124	128	-	-	-	-	-	-
7	Opisthion basion length (7)	32	34	-	-	-	-	-	-
8	Maximum cranial breadth (8)	128	137	(138)	(140)	-	117	125	-
9	Minimum frontal breadth (9)	92	90	86	86	(96)	-	-	-
10	Maximum frontal breadth (10)	111	105	102	100	(104)	-	-	-
11	Bi-auricular breadth (11)	108	(116)	-	-	-	-	-	-
12	Greatest occipital breadth (12)	104	104	(110)	-	-	100	-	-
13	Bi-mastoid breadth (13)	93	(96)	-	-	-	-	-	-
14	Breadth of foramen magnum (16)	27	26	-	-	-	-	-	-
15	Basion-bregma height (17)	119	124	-	-	-	-	-	-
16	Basion vertex height (17-2)	-	-	-	-	-	-	-	-
17	Auriculo bregmatic height (20)	-	-	-	-	-	-	-	-
18	Porion (auriculo) vertex height (21)	-	-	-	-	-	-	-	-
19	Calvarial height (22)	-	-	-	-	-	-	-	-
20	Lambda calvarial height (22b)	-	-	-	-	-	-	-	-
21	Frontal perpendicular height (22e)	-	-	-	-	-	-	-	-
22	Parietal perpendicular height (22f)]	-	-	-	-	-	-	-	-

(Table 1 Continued…)

(Table 1 Continued…)

S.No.	Measurement	Sp. I	Sp. II	Sp. III	Sp. IV	Sp. V	Sp. VI	Sp. VII	Sp. VIII
23	Occipital perpendicular height (22g)	-	-	-	-	-	-	-	-
24	Horizontal circumference of skull (23)	498	502	-	-	-	-	-	-
25	Transverse arc (24b)	289	(300)	-	-	-	-	-	-
26	Longitudinal arc (25)	361	362	-	-	-	-	-	-
27	Frontal arc (26)	120	125	130	128	125	-	-	-
28	Parietal arc (27)	129	126	110	104	-	117	-	126
29	Occipital arc (28)	112	111	-	-	-	110	-	-
30	Frontal chord (29)	101	108	104	108	109	-	-	-
31	Parietal chord (30)	118	111	104	105	-	106	-	113
32	Occipital chord (31)	92	92	-	-	-	88	-	-
33	Facial length, facial depth (40)	95	-	-	-	-	-	-	-
34	Lower facial length, (42)	-	-	-	-	-	-	-	-
35	Outer bi-orbital breadth, (43)	98	-	-	-	-	-	-	-
36	Inner bi-orbital breadth (43-1)	90	-	-	-	-	-	-	-
37	Bi-orbital breadth (44)	92	-	-	-	-	-	-	-
38	Bi-zygomatic breadth (45)	115	-	-	-	-	-	-	-
39	Breadth of upper jaw (46)	89	-	-	-	-	-	-	-
40	Morphological facial height (47)	-	-	-	-	-	-	-	-
41	Upper facial height, (48)	58	-	-	-	-	-	-	-
42	Breadth of nasal root (49)	-	-	-	-	-	-	-	-
43	Anterior inter-orbital breadth (50)	22	-	-	-	-	-	-	-

(Table 1 Continued…)

(Table 1 Continued…)

S.No.	**Measurement**	**Sp. I**	**Sp. II**	**Sp. III**	**Sp. IV**	**Sp. V**	**Sp. VI**	**Sp. VII**	**Sp. VIII**
44	Orbital breadth (51), Right	38	-	-	-	-	-	-	-
	Left	38	-	-	-	-	-	-	-
45	Orbital height (52), Right	33	-	-	-	-	-	-	-
	Left	32	-	-	-	-	-	-	-
46	Nasal breadth (54)	24	-	-	-	-	-	-	-
47	Nasal height (55)	41	-	-	-	-	-	-	-
48	Length of Nasal bones (56)	-	-	-	-	-	-	-	-
49	Maxillo-alveolar length (60)	46	-	-	-	-	-	-	-
50	Maxillo-alveolar breadth (61)	58	-	-	-	-	-	-	-
51	Sub-nasal height (48-1)	19	-	-	-	-	-	-	-
52	Palatal length (62)	39	-	-	-	-	-	-	-
53	Palatal breadth (63)	41	-	-	-	-	-	-	-
54	Palatal height (64)	17	-	-	-	-	-	-	-
55	External palatal arc (80)	133	-	-	-	-	-	-	-
56	Molar teeth row length (80-3), Right	13	-	-	-	-	-	-	-
	Left	13	-	-	-	-	-	-	-
57	Premolar teeth row length (80-3a), Right	27	-	-	-	-	-	-	-
	Left	27	-	-	-	-	-	-	-

1. Infectious disease
2. Traumatic lesion
3. Morphological changes
4. Porosity
5. Anomalies

Observations

Age Estimations

The remains in Roopkund display a wide range of ages, from adolescents to adults (see Table 2). Within the 27 studied samples, one individual (3.7%) has been identified as a young adult (20-35 years of age), ten individuals (37.3%) as middle-aged persons (35-49 years of age), six individuals (22.2%) as elderly people (50+ age), and another six individuals (22.2%) as a member of the adult age group. There were four specimens (14.8%) where age estimation could not be done.

Sex Determination

In the present investigation, sex determination using the skull and other fragmentary skull pieces was a challenging task. In two of the 27 investigated specimens (the skull and the cranium), the sex could be identified with certainty. One was identified as a male and the other as a female. In addition, there were a total of four individuals who are most likely to be male and five individuals who are most likely female. For 16 specimens, it was impossible to ascertain their sex (see Table 3). It's crucial to remember that only two specimens exhibit the most observational traits.

Pathology

There were more than 20 out of 27 studied skull samples with porotic pathological findings in the form of hyperostosis and cribra orbitalia. All the pathologies have been observed with naked eyes. In 16 individuals, porosity on the outer surface of the skull and alongside the sagittal suture on the parietal bone near the vertex were recorded (Figs. 5-7, Table 4). In some remains, porosity has been found on the frontal bone above the supraorbital ridge and the occipital bone just above the external occipital protuberance. Inner cranial surface pitting—a kind of porosity—has been recorded in individual XIV (Fig. 8). And, one thing to note here is that the porosity in some individuals is very compact, whereas it is very light in others. Pitting or macro porosity was also observed at the supraorbital region in one specimen.

The severity of the porosity is graded at 3 in 9 samples, 2 in 5 samples, and 1 in 2 samples. Porotic hyperostosis with sagittal sutures on both partial bones appears to be severe and is graded 3 out of 5. A woven kind of formation has been observed on the inner wall of the occipital bone of individual XIX (Fig. 9). Porosity in the form of cribra orbitalia has also been observed at the orbital walls of individuals III, V and XXIV (Figs. 10-11). In individual XXIV, the porosity is present in the form of pitting. Individuals III and V have micro porosity on the orbital wall. The severity of the porosity is graded from 1 to 3.

Table 2: Estimated Age Distribution of Roopkund Remains

Categorized age group of the remains	**Numbers**	**Average % of total estimated age samples**
Young adult (20-35 year)	01	3.7%
Middle-aged adult (35-49 year)	10	37.03%
Old aged adult (50+)	6	22.2%
Adult	6	22.2%
Not estimated	4	14.81%
Total	**27**	**100%**

Table 3: Identified Sex Distribution of Roopkund Remains

Identified sex	**No. of samples**	**Average % of total diagnosed samples**
Male (confirmed)	01	3.7%
Male (probable)	04	14.9%.
Total	**05**	**18.6%**
Female (confirmed)	01	3.7%
Female (probable)	05	18.5%
Total	**06**	**22.2%**
Unidentified	16	59.5%
Grand total	**27**	**100%**

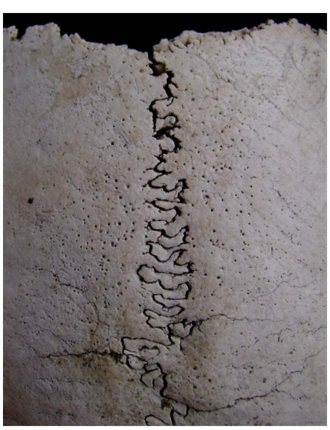

Fig. 5: Porosity alongside of sagittal suture on parietal bone (hyperostosis) (Skull VI)

Fig. 6: Porosity alongside of sagittal suture on parietal bone (hyperostosis) (Skull XII)

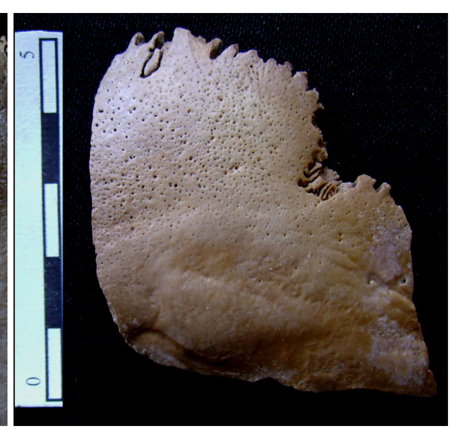

Fig. 7: Porosity on occipital bone (hyperostosis) (Skull XXIII)

Table 4: Pathological Description of Roopkund Cranial Remains

S.No.	Sp.No.	Age of the individual	Sex of the individual	Affected areas	Problem				Remarks
					Porosity/ Infection	Trauma	New bone/ osteoblast/ bone growth	Lipping/ osteophytic growth	
1	II	MAA (45)	F	Frontal bone, left orbit	-	Wound marks	Spine kind of growth in left orbit	-	Morphological
2	III	MAA (45)	CD	Orbit	P (1) cribra orbitalia	-	-	-	Iron and vitamin C,D deficiency
3	IV	MAA (45)	PM	Vertex / along the lamboid suture, left side of frontal bone	P (2)	Anti – mortem fracture	-	-	Fracture and non- specific infection due to iron and vitamin C,D deficiency
4	V	MAA (45)	PF	Roof of right orbit, vertex	P (3) cribra orbitalia)	Depression	-	-	Morphology and non-specific infection due to iron and vitamin C,D deficiency
5	VI	MAA (40)	PM	Along the saggital suture, on the parietal bone, near the temporal line	P (3)	-	-	-	Non-specific infection or iron and vitamin C,D deficiency

(Table 4 Continued…)

(Table 4 Continued…)

S.No.	Sp.No.	Age of the individual	Sex of the individual	Affected areas	Problem				Remarks
					Porosity/ Infection	Trauma	New bone/ osteoblast/ bone growth	Lipping/ osteophytic growth	
6	VII	50+	CD	Across the sagittal suture / both parietal	P (3)	Completely healed fracture	-	-	Anti-mortem fracture and non-specific infection due to iron and vitamin C,D deficiency
7	VIII	MAA (40-45)	CD	Left and right parietal, occipital	?	Anti mortem crack/ swelling/ depression	Nod kind of bone growth	-	Crack may be the cause of death, nod is osteomata and non-specific infection due to iron and vitamin C, D deficiency
8	IX	MAA (+50)	CD	Near the suture, middle of the parietal bone	P (3)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
9	X	MAA	PM	Frontal bone and supra orbital region	P (2)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
10	XI	YA	CD	Right parietal on inner table	P (2)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
11	XII	MAA	CD	Vertex/along sagittal and lamboid sutures, near the obelion	P (3)	Anti mortem fracture	-	-	Fracture may be the cause of death, non-specific infection or iron and vitamin C, D deficiency

(Table 4 Continued…)

(Table 4 Continued…)

S.No.	**Sp.No.**	**Age of the individual**	**Sex of the individual**	**Affected areas**	**Problem**				**Remarks**
					Porosity/ Infection	**Trauma**	**New bone/ osteoblast/ bone growth**	**Lipping/ osteophytic growth**	
12	XIII	Adult	CD	Vertex, along the lemboid suture	P (3)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
13	XIV	(Adult)	PF	Occipital bone on inner table	P (2)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
14	XVI	(OA)	CD	Near saggital suture, endocranial surface	P (2)	-	-	-	Non-specific localize infection or iron and vitamin C, D deficiency
15	XVII	(Adult)	CD	Occipital bone	P (1)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
16	XVIII	(MAA)	CD	Above the inion, endocranial surface	P (3)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
17	XXI	-	PF	On the whole surface	P (3)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
18	XXIII	Adult (MAA)	CD	Occipital bone near the suture	P (3)	-	-	-	Non-specific infection or iron and vitamin C, D deficiency
19	XXIV	-	CD	Orbit	P (3) cribra orbitalia	-	-	-	Iron and vitamin C, D deficiency

MAA= Middle-aged adult, YA= Young adult, OA= Old adult, CD= Cannot be determined

Fig. 8: Porosity and woven formations on the inner surface of occipital bone (Skull XIV)

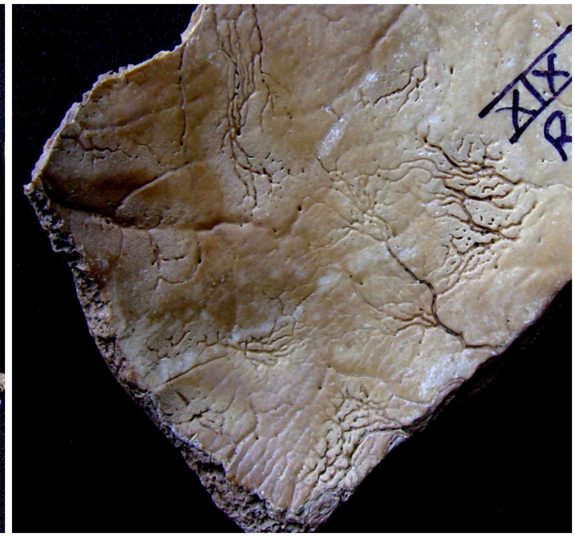

Fig. 9: Porosity and woven formations on the inner surface of occipital bone (Skull XIX)

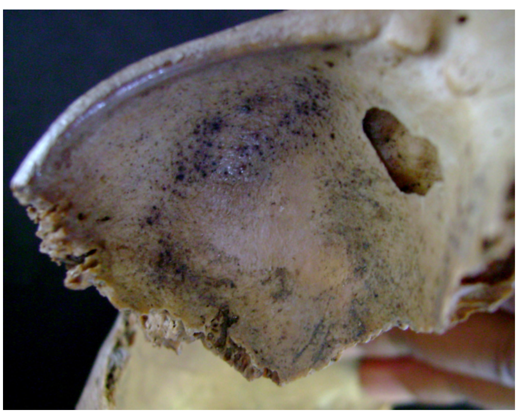

Fig. 10: Porosity on the orbital wall (Cribra Orbitalia) (Skull V)

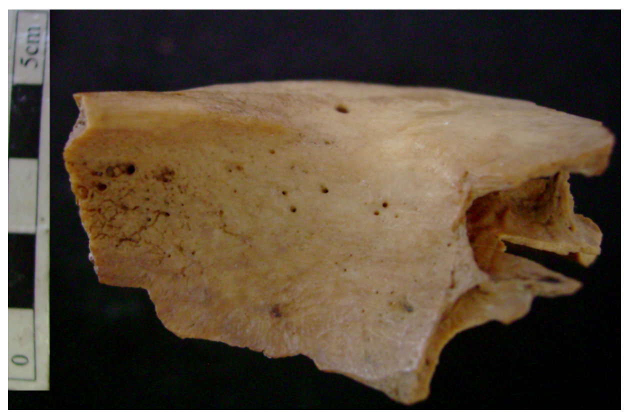

Fig. 11: Porosity on the orbital wall (Cribra Orbitalia) (Skull XXIV)

Discussion

Pathological observations revealed severe porosity on the majority of the skull remains, especially alongside the sagittal suture on the parietal bone near the vertex area. Porosity is also evident in the vault and orbit. This kind of porosity definitely appears when a person is suffering from anaemia. Anaemia is always caused by a long-term lack of essential nutrients such as iron, vitamin C, and vitamin D, as well as a lack of fresh food and adequate sunlight. Cribra orbitalia is again the result of severe anaemia (e.g., Ortner 1975, 2003; Aufderheide and Rodriguez-Martin 1998; Blom et al. 2005; Oxenham and Cavill 2010; Jatautis et al. 2011; Suby 2014). Roopkund is located at an altitude of more than 5000 m. As a result, high-altitude weather conditions and topography always result in a lack of fresh food and adequate sunlight for the people. It is worth noting that, as of today, the Roopkund trail covers approximately 35 km from the last bus stop and takes

3 to 4 days from the valley's last village. This area covers the altitude range of 1500–5000 m in the middle Himalaya. So, seeing today's environmental and geographical toughness of the Roopkund Track area, we can estimate the geography and weather hardiness of thousands of years ago. It could be possible that the evidence of porosity visible on the bones is the result of short-term anaemia; caused by the long lack of fresh food, proper sunlight, which might have occurred to these victims during their visit to Roopkund (other possibilities also cannot be ignored). However, it is certain that this was not the root cause of the sudden deaths of the Roopkund victims.

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