ON-SITE EVALUATION OF THE PRESERVATION OF HUMAN BONES UNEARTHED IN XI 'AN AREA

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Background

Ancient human skeletons constitute exceptional archives for reconstructing our species' biological and cultural history, yet archaeologists still lack standardized, field-deployable protocols for evaluating their preservation status at the moment of discovery. While taphonomic research in Europe and North America has clarified broad diagenetic pathways , Chinese efforts have concentrated on post-excavation consolidation and conservation. The absence of an integrated, quantitative framework for in-situ assessment limits both the scientific rigour of subsequent osteoarchaeological analyses and the effectiveness of on-site conservation decisions.

Aim

To develop, calibrate and field-validate a rapid, non-destructive decision-support protocol that **(i) quantifies the real-time preservation risk of freshly exposed human skeletal remains, (ii) ranks extraction urgency on a continuous scale, and (iii) translates these data into specimen-specific protocols for lifting, stabilization, packaging and transport.**

This study seeks to establish the first evidence-based workflow that can be deployed by field archaeologists without specialized laboratory equipment, thereby closing the critical gap between in-situ discovery and post-excavation conservation.

Methodology

(i) Samples: 25 newly exposed individuals from Xipocun cemetery and 9 from Tuanjiecun cemetery, Xi'an city, China.

(ii)Indicator system: established an on-site data-acquisition protocol for intrinsic skeletal indicators—namely the Bone Preservation Index (API), Bone Representation Index (BRI), completeness score, D-type digital Shore-D hardness tester, and ZC5 mortar rebound hammer—and for burial-environment indicators using the LY-201 digital soil analyser.

(iii)Analytical workflow: after data normalization, entropy weighting was applied to derive objective indicator weights; TOPSIS was then used to calculate each specimen's relative approach degree(C_i) to the ideal preservation state and to rank urgency of intervention.

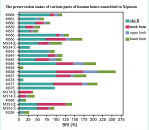

Figure 1: BRI histogram of bone representative index of human bones unearthed from Xipocun cemetery

Number	Positive ideal solution distance $D+$	Negative ideal solution distance $D-$	Relative approach degree C_i	Ranking results
M326	0.341	0.132	0.279	17
M353①	0.213	0.254	0.544	7
M353②	0.187	0.311	0.625	2
M368	0.351	0.199	0.361	16
M374①	0.360	0.101	0.218	22
M374②	0.390	0.053	0.120	23
M375	0.393	0.040	0.092	25
M377	0.212	0.223	0.513	10
M378	0.371	0.117	0.240	20
M537	0.205	0.241	0.540	8
M538	0.075	0.357	0.826	1
M539	0.247	0.242	0.495	11
M546	0.192	0.237	0.553	5
M548	0.260	0.172	0.398	14
M549	0.265	0.175	0.398	15
M553	0.339	0.131	0.279	18
M554①	0.391	0.053	0.118	24
M554②	0.225	0.250	0.526	9
M555	0.188	0.232	0.552	6
M556	0.187	0.255	0.577	4
M557	0.347	0.113	0.246	19
M559	0.255	0.171	0.401	13
M560	0.355	0.107	0.231	21
M561	0.236	0.198	0.457	12
M568	0.186	0.260	0.582	3

Table 1: The evaluation results of the preservation status of human bones unearthed from the Xipocun cemetery

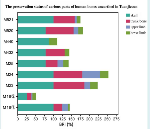

Figure 2: BRI histogram of bone representative index of human bones unearthed from Tuanjiecun cemetery

Number	Positive ideal solution distance $D+$	Negative ideal solution distance $D-$	Relative approach degree C_i	Ranking results
M18①	0.249	0.211	0.459	6
M18②	0.355	0.088	0.198	9
M23	0.099	0.310	0.758	3
M24	0.074	0.341	0.821	1
M25	0.286	0.202	0.414	7
M432	0.216	0.220	0.505	5
M440	0.358	0.096	0.211	8
M520	0.091	0.361	0.799	2
M521	0.123	0.291	0.703	4

Table 2: The evaluation results of the preservation status of human bones unearthed from the Tuanjiecun cemetery

Figure 3-5: Data collection work at the archaeological site. From left to right : Fig.3 is the use of D-type digital Shore-D hardness tester, Fig.4 is the use of ZC5 mortar rebound hammer, Fig.5 is the use of LY-201 digital soil analyser.

Results

(i)Xipocun cemetery: C_i= 0.407 (range 0.092–0.826). Twelve individuals exceeded this threshold, indicating low extraction urgency; 13 individuals fell below and required immediate recovery and specimen-specific stabilization. (ii)Tuanjiecun cemetery: C_i = 0.541 (range 0.198–0.821). Four specimens were low-priority; five required urgent intervention.

(iii)Entropy weighting minimized subjective bias, accurately quantifying the contribution of each indicator; the subsequent TOPSIS ranking delivered objective, data-driven guidance for lifting, conservation, and transport decisions. Across both sites, model scores corresponded closely to observed preservation states, and the resulting extraction and treatment recommendations have already been successfully implemented on-site, confirming the method's feasibility and operational value.

Conclusion

We present and validate an integrated, field-deployable protocol that couples entropy-weighted TOPSIS with intrinsic skeletal indicators and burial-environment variables, enabling rapid, non-destructive, and reproducible preservation assessments for human skeletal remains at the point of excavation. The entropy-weighted TOPSIS model objectively quantifies indicator weights and generates a ranked preservation index for every specimen, yielding unambiguous scores that translate directly into targeted conservation prescriptions. This evidence-based workflow equips field teams with practical, specimen-specific guidance for the extraction, stabilization and transport of newly exposed human remains, safeguarding both structural integrity and long-term stability. By bridging conservation practice and osteoarchaeological research, the framework provides a transferable benchmark for developing health-assessment standards for excavated osseous artefacts and accelerates the scientific and procedural standardization of cultural-heritage conservation worldwide..

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