Role and Management of Forensic Anthropology and Forensic Medicine in Estimating Sex and Age of the Yazidi Kurdish Mass Grave in Kojo, Near the Sinjar Area

Prof. Dr. Yasin Kareem Amin

Assist Prof. Dr. Muhsen Kamal Yasen

Abstract

Background:

Following the 2014 attacks on Sinjar, multiple mass graves were documented in Kojo village. Many victims were exhumed and transferred to Baghdad for medicolegal examination and humanitarian identification. In largescale recovery operations, pelvic and cranial elements are not always available or sufficiently preserved; consequently, long bones (femur and forearm) become critical for sex estimation and for crosschecking age assessments.

Objective: To evaluate whether measurements of the left femur and left forearm (radius + ulna complex, measured as forearm length) can aid sex estimation and support age profiling in a cohort of exhumed individuals from Kojo, and to summarize practical management steps that supported ethical, scientific, and culturally sensitive handling of remains.

Materials and Methods: We reviewed 382 skeletonized sets of remains meeting strict inclusion criteria (intact left femur and left forearm; adult epiphyseal status) and excluding cases with extensive burning, mutilation, advanced taphonomic alteration, or prior major trauma/ deformity. Standard osteological procedures and chainofcustody protocols were applied. Longbone lengths were recorded; descriptive statistics and group comparisons were conducted to explore sexual dimorphism and agerelated patterns within the available data.

Results: The mean left femur length was 31.40 ± 11.91 cm and the mean left forearm length was 24.02 ± 9.12 cm. The difference between these means was statistically significant ($p < 0.001$). Of 342 sexed individuals, 146 (42.7%) were male and 196 (57.3%) were female. Age profiling identified 199 (58.2%) adults, 139 (40.6%) older adults, and 4 (1.2%) subadults.

Conclusions: In absence of pelvic or cranial landmarks, femur and forearm measurements provide practical adjuncts to sex estimation in this population and context. Such measurements should be applied alongside broader metric and morphological assessments and, wherever possible, genetic testing. The experience from Kojo highlights not only analytical techniques but also the operational management—documentation, storage, and familycentered return—that underpins dignified identification.

Keywords: Forensic anthropology; mass graves; Kojo; Sinjar; Yazidi; sex estimation; long bones; femur; forearm; humanitarian identification; Iraq.

1. Introduction

Forensic anthropology and forensic medicine are central to identifying Yazidi victims from Kojo by estimating sex and age from skeletal remains. The mass graves near Sinjar reflect systematic, intentional violence and underscore the need for rigorous, rights-based scientific investigation. This study aims to estimate sex using forensic anthropological metrics from recovered skeletons and to profile age based on epiphyseal fusion and related indicators. It also records selected forensic-medical observations of bone trauma consistent with inhuman injuries.

Accurate identification in mass-grave contexts requires robust methods for sex, age, and ancestry. Discriminant-function analysis remains a cornerstone for classifying individuals from skeletal dimensions; while lengths, widths, and diameters are well validated, circumferences and volumetric measures are less studied, limiting utility when remains are fragmentary or taphonomically altered (Spradley & Jantz, 2016; Safont et al., 2000). The Yazidi genocide of 2014—especially the Kojo sites—demands precise and culturally sensitive protocols, integrating anthropology, odontology, and pathology to restore identities and support justice (OHCHR, 2016; UNITAD, 2021).

Sex estimation typically prioritizes pelvis and skull due to marked sexual dimorphism (e.g., mastoid processes, supraorbital ridges, sciatic notch) (Kenyhercz et al., 2017). In incomplete remains common to conflict settings, long bones (e.g., femur, humerus) offer reliable alternatives, with males generally exhibiting greater robusticity and thicker cortices (Gonzalez et al., 2021). Advances in geometric morphometrics and machine-learning have further improved classification, and teeth provide additional evidence through odontometric dimorphism and DNA from dental pulp (Luna et al., 2020; Cameriere et al., 2019; Kumar et al., 2014).

Age estimation is complicated by population specificity and environmental stress. The Yazidi community may diverge from global reference datasets, warranting careful calibration of methods such as pubic symphysis metamorphosis, cranial suture closure, and dental cementum annulation (Garvin & Passalacqua, 2021). Subadult assessments relying on diaphyseal length and fusion timelines must consider displacement and deprivation effects (İşcan & Steyn, 2018). Recent work supports multifactorial approaches that combine osteological, dental, and molecular techniques (e.g., aspartic acid racemization) to improve accuracy (Ríos et al., 2023).

Given commingling, scavenging, and blast trauma at Kojo, tailored strategies are essential, including targeted CT imaging and, where appropriate, stable-isotope analysis to refine antemortem matches (Steadman et al., 2018). Ethical management must align with Yazidi cultural practices and kinship systems to ensure dignity and meaningful repatriation (Koch & Flavel, 2022). This study evaluates the utility of circumferential metrics for sex estimation and refines age-at-death approaches suited to Yazidi populations, advancing both forensic practice and the broader humanitarian effort.

0.1. Background of the Yazidi Kurdish Mass Grave in Kojo

On August 3, 2014, ISIS attacked the Yazidi Kurdish community. Many fled; those who could not were killed, and numerous women and children were abducted and sexually assaulted. The European Parliament (2016) and the United Nations later recognized these crimes as genocide. Mass graves are scattered across Sinjar; this study focuses on Kojo, near Sinjar, and estimates the sex and age of those interred (Gilligan, 2018). The Kojo grave was identified through survivor testimony and satellite imagery. In the absence of a forensic archaeology team, a local crew began excavation with a bulldozer. Eighty-six sets of remains and four possible human bones were documented; formal civilian identifications are pending, and the case warrants comprehensive forensic investigation. The skeletonized remains—transported from Kurdistan to Germany—show post-excavation alterations (e.g., fissures). Before analysis, bones

were hand-cleaned under anthropological supervision. Management follows international guidance on dignified handling of the dead; rough treatment harms families and undermines rights. Although the excavation occurred under urgent, suboptimal conditions, the case demands careful, rights-based scientific review.

0.2. Sex Estimation Methods in Forensic Anthropology

0.2.1. Sex Estimation Methods in Forensic Anthropology

Sex estimation is a foundational step in establishing the biological profile of unknown human remains. In forensic anthropology, sex is inferred by evaluating sexually dimorphic traits—either visually (morphoscopic assessment) or metrically using statistical models—recognizing that dimorphism reflects hormonal and developmental influences on the skeleton (Holbeck, 2022). The pelvis and cranium are the most informative regions due to their pronounced dimorphism and relative durability: pelvic features related to parturition and cranial robusticity (e.g., mastoid size, supraorbital margins) commonly yield the highest accuracies when preserved.

When axial elements are incomplete—as is frequent in mass-grave or taphonomically altered contexts—metric assessment of long bones (e.g., femur, humerus), the mandible, or selected circumferences can provide useful adjunct evidence through discriminant functions or Bayesian/ML classifiers (De Donno et al., 2021). Best practice requires: (i) population-appropriate reference data to minimize bias; (ii) explicit reporting of method limits; and (iii) controls for inter- and intra-observer error. Accuracy can be degraded by commingling, fragmentation, heat alteration, and preservation biases. Juvenile and subadult remains are especially challenging because sexual dimorphism is less developed. Accordingly, sex opinions should be expressed with confidence levels and, where feasible, corroborated with odontology and DNA.

0.2.2. Age Estimation Methods in Forensic Anthropology

Age-at-death is estimated through macroscopic indicators, metric analyses, and, when available, microscopic or molecular techniques. Method selection depends strongly on whether the remains are subadult or adult:

Subadults: Dental development/eruption and epiphyseal ossification/fusion provide the most reliable age estimates. Diaphyseal length and tooth formation charts allow relatively narrow intervals but must account for population variation and environmental stressors (Correia Dias et al., 2021; Phulari & Dave, 2021).

Adults: Ageing relies on degenerative changes with broader uncertainty—classically the pubic symphysis and auricular surface morphology, sternal rib ends, and (with caution) cranial suture closure. These indicators should be combined in a multifactorial framework to avoid overreliance on any single trait (De Donno et al., 2021).

Advanced avenues include geometric morphometrics, imaging (e.g., CT-based trabecular metrics), cementum annulation, and biochemical approaches (e.g., aspartic-acid racemization), which can refine estimates when validation exists for the target population (Parra et al., 2025; Correia Dias et al., 2021). Across all methods, performance is influenced by preservation, commingling, and scorer expertise; therefore, transparent confidence ranges and method citations are essential.

Identification in mass-fatality settings often begins with sex and age because these narrow the search space and inform assessments of perimortem trauma and victim matching. The Kojo assemblage—recovered from a mass grave in an archaeological setting—was triaged and examined accordingly, with skeletal profiles integrated into the broader forensic investigation (Phulari & Dave, 2021).

0.3. Forensic Medicine in Estimating Sex and Age

Forensic medicine (forensic pathology) and forensic anthropology are complementary in mass-grave investigations such as Kojo. In this case—

reportedly involving members of a single extended family with many execution-style gunshot injuries—forensic medicine contributes to:

Cause and manner of death analysis: Documentation of trauma patterns on any preserved soft tissues and, more commonly in ossuary contexts, bone lesions consistent with gunfire (entrance/exit defects, beveling, radiating/concentric fractures).

Imaging and sampling: Radiography/CT to detect embedded projectiles or fractures; standardized sampling for DNA and, where soft tissue persists, limited toxicology.

Chain-of-custody and reporting: Integration of medical findings with anthropological profiles to support identification and legal processes.

Because Kojo remains are predominantly skeletonized, traditional autopsy markers of hemorrhage or coagulation are typically absent; interpretation therefore relies on osseous evidence, imaging, scene context, and interdisciplinary review. Associated materials (e.g., four sherds of common clay pottery) are recorded archaeologically to preserve context and potential associative value. Bone-based age estimation uses established anthropological criteria (e.g., epiphyseal fusion, pubic symphysis/auricular changes, dental indicators) and is reported with explicit confidence intervals (Bonicelli et al., 2021; De Donno et al., 2021).

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0.4. Role of management and administration

In mass-fatality investigations like Kojo, sound management and administration are not side issues—they are the scaffolding that lets rigorous science, cultural dignity, and timely return of loved ones happen. Leadership establishes a governance structure with clear lines of authority (scene → laboratory → reporting) and standard operating procedures (SOPs) that hold those links together: intake checklists, chain-of-custody forms, labeling conventions, photo logs, sampling registers, and audit trails. These are not mere paperwork; they are the safeguards that prevent mis-association, data loss, and repeat sampling, and they enable clean integration of osteology, odontology, imaging, and DNA into a single case narrative. In Kojo, that means unique identifiers assigned at recovery, verified at every handover, and mirrored across paper and digital records—small disciplines that pay enormous dividends for accuracy and trust (ICRC/ WHO, 2016).

Good administration plans for people as much as for procedures. Schedulers coordinate multidisciplinary shifts; case managers define reviewer sign-offs and convene case conferences so difficult classifications (e.g., sex estimates from incomplete remains) receive second-examiner oversight. Training is continuous and practical: refreshers on measurement error, briefings on taphonomy and heat alteration, and tabletop exercises for evidence transfer. These quality-assurance habits reduce inter-observer variability and create a shared vocabulary for confidence levels and limitations (Klales, 2020; Goldstein et al., 2022). As Adams et al. (2022) argue, leadership must also cultivate a culture of care and reflexivity—making space for ethical deliberation, documenting value judgments in casework, and ensuring that "how" we work is as deliberate as "what" we conclude.

Family-facing management is equally central. Administrators maintain transparent communication with families and community representatives, ensuring informed consent for sampling, clarifying timelines, and arranging viewings or dignified returns consistent with Yazidi practices. Ethics committees and community liaisons help navigate questions around destructive testing, secondary burials, and memorialization. International

guidance is clear: plan early for respectful handling, robust documentation, and identification; keep families informed at every turn (ICRC, 2016; WHO, 2016). Passalacqua et al. (2022) underscore that stewardship responsibilities do not end at the lab door; institutional policies must explicitly protect unidentified cases, define custodianship, and resource long-term care.

Information management underpins everything. A secure case database should tie scene context, measurements, photographs, radiographs/CT, dental charting, and DNA barcodes to the same unique ID, with role-based access, automatic versioning, and routine backups. Simple dashboards help leaders track key performance indicators—turnaround time to DNA submission, sample rejection rates, chain-of-custody discrepancies, backlog size—so resources can be shifted before bottlenecks form. Regular internal audits and external peer review anchor continuous improvement (WHO, 2016).

Resource and risk management are pragmatic responsibilities. Procurement ensures measurement boards, calipers, PPE, cold-storage capacity, and evidence packaging are stocked and calibrated; logistics solves for transport, temperature control, and scene security. A basic risk register—covering heat, dust, commingling, contamination, and information-security threats—assigns owners and mitigations (e.g., two-person measurements for long bones; photographed setups with scale and ID; double-entry data). When incidents occur, a no-blame "near-miss" culture encourages reporting and rapid corrective action.

Finally, good administration documents decisions. When pelvic or cranial landmarks are unavailable, the rationale for using adjunct long-bone metrics, the confidence attached to that opinion, and the plan to corroborate with DNA should be explicitly recorded. This transparency strengthens legal defensibility and honors families by making the reasoning legible (Klales, 2020; Palamenghi et al., 2024). In short, management and administration

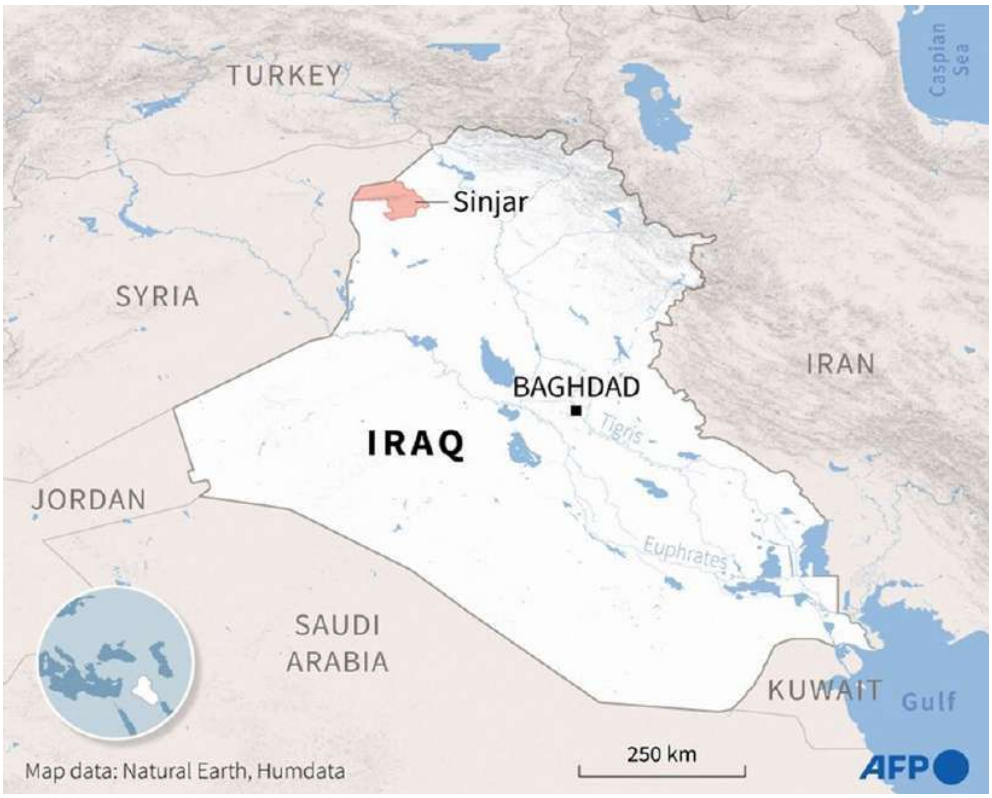

Figure 1: Study area

translate scientific intention into dependable outcomes—quiet, methodical work that turns chaos into clarity and, ultimately, enables dignified identification and return

1. Materials and Methods

1.1. Case selection and inclusion criteria

A total of 382 skeletonized sets of remains were examined. Inclusion required: (i) intact left femur and left forearm suitable for measurement; (ii) full epiphyseal union indicating adulthood, unless otherwise specified; and (iii) minimal taphonomic damage interfering with measurement landmarks. Exclusions included: (i) extensive burning (≥ ~50% cortical charring); (ii) dismemberment or toolmark mutilation compromising length measures; (iii) partial skeletonization with major longbone loss; (iv) severe postmortem alterations (scavenging, erosion) obscuring landmarks; and (v) clear antemortem fractures, congenital anomalies, or known pathology affecting femoral or forearm lengths.

1.2. Location and Context of the Mass Grave

The mass grave site is situated in the mountainous region of Kojo, near the city of Sinjar, in the autonomous province of Iraqi Kurdistan, around 15 km from the Syrian border. The mass grave is located in a depression on the outskirts of two small Yazidi villages, with a small walled graveyard nestled directly above. The terrain consists of dark brown, open, arid slopes with scant vegetation, sunbaked into hard, steep contours by the scorching sun. Clumps of unwelcoming thorn bushes dot the hillside, and the ubiquitous loose rocks of the sinjarite foothills make each step treacherous on a combination of loose shale and fine scree. Smugglers regularly traverse the nearby valley traversed by the mass grave, and those excavating the site are warned to look out for them stealing antiquities or artifacts. The view to the north is of the circling Sinjar Mountains, which rise sharply from the plain and are characterized by wide barren plateaus and steep slopes covered in bright white gypsum deposits. In August the temperatures in the area regularly reach up to 50°C.

1.3. Scene recovery and chainofcustody (summary)

Recovery followed bestpractice massgrave protocols: scene mapping; controlled stratigraphic excavation; unique case identifiers; evidentiary photography; and immediate packaging of skeletal elements. At every handover—from scene to transport, and from reception to storage—records were signed and timestamped. Each case file combined excavation context, bodybag labels, and subsequent laboratory notes. This continuity allowed confidence in linking osteological findings to DNA results and family reports. Field procedures accounted for known risks in clandestine or reworked graves (e.g., backhoe reinterment patterns), drawing on published guidance from comparable contexts (Gilligan, 2018; Borić et al., 2011).

1.4. Osteological examination and measurement protocol

All longbone measurements were taken on the left side to avoid bilateral duplication. Femur length was measured from the most superior aspect of the femoral head to the most inferior point of the medial condyle (maximum physiological length), using anthropometric boards where feasible and large calipers or tapeandplumb techniques when necessary.

Landmarks and handling:

• Femur: Head apex to medial condyle lowermost point; if epiphyseal damage was present, the lesser trochanter plane was documented and a conditional estimate flagged.

• Radius: Radial head superior rim to radial styloid apex.

• Ulna: Olecranon tip to ulnar styloid apex.

• Forearm operative value: When both bones were intact, both lengths were recorded; the primary

value for analysis was the radius unless diaphyseal curvature or apical loss made the ulna preferable.

Error management:

• Repeats on 10–15% of cases quantified intraobserver variation.

• Tape sag and parallax were minimized by twoperson measurement and level sighting.

• Warped or bowed shafts were measured with flexible tapes but flagged as caution—nonstraight diaphysis.

Data capture:

• Each value was written on a waterproof field card and entered into a doubleentry spreadsheet.

• A measurement uncertainty column (0 = standard, 1 = minor ambiguity, 2 = major ambiguity) guided downstream interpretation.

1.5. Sex and age assessment

Sex estimation prioritized available pelvic and cranial morphology when present. Where absent or indeterminate, longbone metrics served as an adjunct to classification. The working premise was that, in the reference population, males generally display larger longbone dimensions than females; however, overlap is expected. Age assessment incorporated epiphyseal fusion (adults vs. subadults), degenerative joint changes, and cortical texture. Dental observations informed the rare subadult classifications.

Decision pathway:

1. Check for pelvis or cranial traits; if scorable, classify using composite morphological standards.

2. If not scorable, consult longbone metrics and robusticity patterns; if still equivocal, defer to genetic results.

3. Record confidence (high/medium/low) beside sex and age entries to reflect evidential strength.

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1.6. Data handling and statistics

Measurements and categorical assessments were entered into a standardized database. Continuous variables (femur and forearm lengths) were summarized as means and standard deviations. Group differences were explored using independentsample comparisons, and proportions were tabulated for sex and age categories. Where distributional assumptions were unclear due to postmortem variability, results were interpreted conservatively.

1.7. Quality assurance

Repeated measurements on a subset of specimens established intraobserver consistency. Instruments were calibrated weekly. Any case with measurement ambiguity (e.g., damaged landmarks) was reviewed by a second examiner, and disagreements were resolved by consensus with documentation.

2. Results

2.1. Descriptive measurements

• Left femur length: 31.40 cm (SD 11.91).

• Left forearm length: 24.02 cm (SD 9.12).

• Difference: statistically significant, $p < 0.001$.

The spread of femur length values reflected preservation heterogeneity and natural biological variation. The forearm values showed similar patterns, with occasional rightskew due to particularly long radii/ulnae in presumed male cases.

Table 1. Summary statistics for longbone measurements (cm).

Variable	Mean	SD	Notes
Left femur length	31.40	11.91	Maximum physiological length
Left forearm length	24.02	9.12	Radius/ulna maximum; bestpreserved element prioritized

2.2. Sex distribution

Of 382 total cases, 342 could be sexed with the available criteria. Within this sexed subset, 146 (42.7%) were male and 196 (57.3%) were female. The remainder were indeterminate due to fragmentation or equivocal features.

Table 2. Sex distribution within sexed subset (n = 342).

Sex	n	%
Male	146	42.7
Female	196	57.3

2.3. Age profile

Age assessment indicated 199 (58.2%) adults, 139 (40.6%) older adults, and 4 (1.2%) subadults. The very small number of subadults is consistent with the inclusion criteria favoring epiphyseal fusion, as well as contextual factors in the Kojo events.

Table 3. Age categories (all assessed cases).

Category	n	%
Adult	199	58.2
Older adult	139	40.6
Subadult	4	1.2

2.4. Operational notes

Most Kojo cases arrived with coherent chainofcustody documentation. Packaging quality varied with excavation phase and weather, but postreception rebagging and relabeling minimized data loss. Several remains exhibited heat alteration or perimortem trauma consistent with other reports from the area; these were documented but excluded from measurementbased analyses where appropriate.

2.5. Preservation and taphonomy

Preservation ranged from nearcomplete skeletons with intact articular surfaces to highly fragmentary remains with cortical exfoliation. Heat alteration manifested as color changes (brownblack), surface checking, and, in severe cases, calcination; these were cataloged using a threetier scheme (minor/moderate/severe). Soil chemistry and microroot activity produced localized pitting on diaphyses. Such features informed measurement confidence ratings and shaped the decision to rely more heavily on femoral length than on diaphyseal circumferences in many cases.

3. Discussion

3.1. Interpreting longbone metrics in context

The significant difference between femur and forearm means is anatomically expected and confirms measurement integrity across the cohort. More importantly, the distribution of longbone lengths aligned with the observed sex proportions. While longbone lengths alone cannot achieve the accuracy of pelvic morphology, they remain a practical proxy in massgrave settings where preservation is uneven.

Population specificity matters. Sexing formulae developed in one group can misclassify individuals in another due to differences in body size, nutrition, and ancestry. Accordingly, we treated longbone metrics as supportive rather than determinative unless reinforced by other indicators. The Kojo cohort, composed of Yazidi Kurdish individuals, may differ from reference datasets underpinning classic discriminant functions; hence, our conservative interpretation strategy.

3.2. Comparison with published work

Research across diverse populations has shown that longbone dimensions (lengths and selected circumferences) carry useful sexual dimorphism. The Kojo findings accord with this broader pattern while reminding us of the practical realities: partial

preservation, heat damage, and commingling risks. In particular, femoral dimensions often provide the most stable singlebone signal when pelvis and skull are compromised. Forearm contributions are typically weaker but helpful in triangulation. Recent reviews and method papers support these observations and call for contextspecific baselines and transparent reporting of uncertainty (Klales, 2021; De Donno et al., 2021; Bonicelli et al., 2020; Giesecke, 2001; Parra et al., 2024).

3.3. Age assessment and sampling considerations

Our age profile reflects the methodological focus on fused epiphyses and the context of victim demographics. Because subadults were largely excluded by design, the observed age distribution cannot be generalized to all victims in Kojo. Future analyses should integrate dental development in younger individuals and histological techniques where preservation permits, noting that destructive sampling must be balanced against cultural and ethical constraints.

3.4. Management and logistics: lessons from Kojo

Accurate analysis depends on strong logistics. The Kojo workflow emphasized: meticulous labeling; redundant documentation (written, photographic, and digital); temperaturecontrolled storage; and routine audits of the evidence chain. When families visited the mortuary, staff provided clear explanations of the process and timelines, and psychosocial support was coordinated with community organizations. These steps—though not analytical per se—directly affect identification outcomes by preventing data loss and maintaining trust.

Operational checklist distilled from practice:

• Assign a unique case ID at the scene and crosscheck at every handover.

• Photograph measurement setups beside a scale and ID card.

• Maintain a running log of sampling (DNA, radiography) to avoid duplicate destructive actions.

• Archive measurement uncertainty scores and rationale.

• Schedule periodic case audits to reconcile physical inventory with digital records.

3.5. Integrating odontology and DNA

Dental methods remain essential where dentition is preserved, offering both morphological and metric routes to sex estimation in addition to dental charting for identification. However, in Kojo many crania and mandibles were fragmentary; teeth were not consistently available or were heataltered. Consequently, longbone metrics provided a valuable bridge until genetic results were available. DNA ultimately anchors identification and should be prioritized for final conclusions; osteology guides triage and helps match antemortem reports to laboratory pipelines.

6. Conclusion

In mass-grave contexts like Kojo, long-bone metrics should be used as an adjunct rather than a stand-alone solution: femur and forearm lengths offer practical support for sex estimation when the pelvis and skull are unavailable. Reliable outcomes depend on rigorous chain-of-custody and meticulous documentation so osteological findings integrate cleanly with DNA analyses and family-provided information. Interpretations should remain conservative, explicitly acknowledging population differences and measurement uncertainty and avoiding reliance on single-bone cut-offs. To strengthen future work, teams should invest—ethically and logistically—in building regional reference baselines tailored to Kurdish and neighboring populations. Throughout, families must be at the center of the process, with culturally sensitive engagement and clear pathways for dignified return and reburial. Finally, sustained capacity building is essential: training regional teams in standardized measurement, error control, and robust digital data capture will help maintain quality as caseloads evolve.

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