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Alone in a cave: Examination of a 5200 BCE skeleton from the Judean Desert, Israel

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Abstract: *The remains of a >50-years-old male, thus far representing the only complete skeleton dated to the Early Chalcolithic (Wadi Rabah) period in Israel, were recovered in a cave in the Judaean desert (Nahal Mishmar, F1-003). The old male suffered abscesses in the maxilla following tooth caries, and a well-healed trauma in the left tibial midshaft. Skull and mandibular morphology were described using plain measurements, indices and angles, and compared with similarly taken Chalcolithic data. In addition, mandibular morphology was captured using a landmark-based geometric morphometrics method and compared to Natufian hunter-gatherers, Pre-Pottery Neolithic early farmers, and Late Chalcolithic populations. The results, although cautionary, reveal similarity to the succeeding Ghassulian Chalcolithic period populations and suggest population continuity from the Early to the Late (Ghassulian) Chalcolithic period. Future ancient DNA study may clarify this hypothesis and further reveal population affinity in this period in Israel.*

Key words: Early Chalcolithic period; biological anthropology; Judean Desert; skeletal morphology

Introduction

Despite over a hundred years of extensive excavations in Israel, and numerous studies dedicated to prehistoric skeletons in the Southern Levant, little is known of the people of the Late Pottery Neolithic / Early Chalcolithic (ca. 5,800–4,500 cal. BCE). Unlike the Pre-Pottery Neolithic (PPN; ca. 9,500–6,500 cal. BCE), which have been extensively studied (e.g., Bocquentine et al. 2016; Hershkovitz et al. 1986; Sklar-Parnes & Smith 2003), and the Ghassulian Chalcolithic (ca. 4500–3700 cal. BC) populations,

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which have been described in detail by bioarchaeologists (e.g., Agelarakis et al. 1998; Lev-Tov et al. 2003; Nagar 2013; Smith & Sabari 1995), few descriptions and studies on the burial practices, demography, pathology, and morphology of skeletons of the 6th and 5th millennia BCE have been carried out. Therefore, wide-ranging theories concerning the biological history of the populations of Israel have largely omitted this transitional period due to lack of information (Arensburg 1973, Nagar 2003, Smith 1998).

In the recent years, a survey on available burials dating to this forgotten period was published by Gopher and Eshed (2012). Furthermore, salvage excavations with burials from this transitional period have been carried out (Galili et al. 2009; Milevski

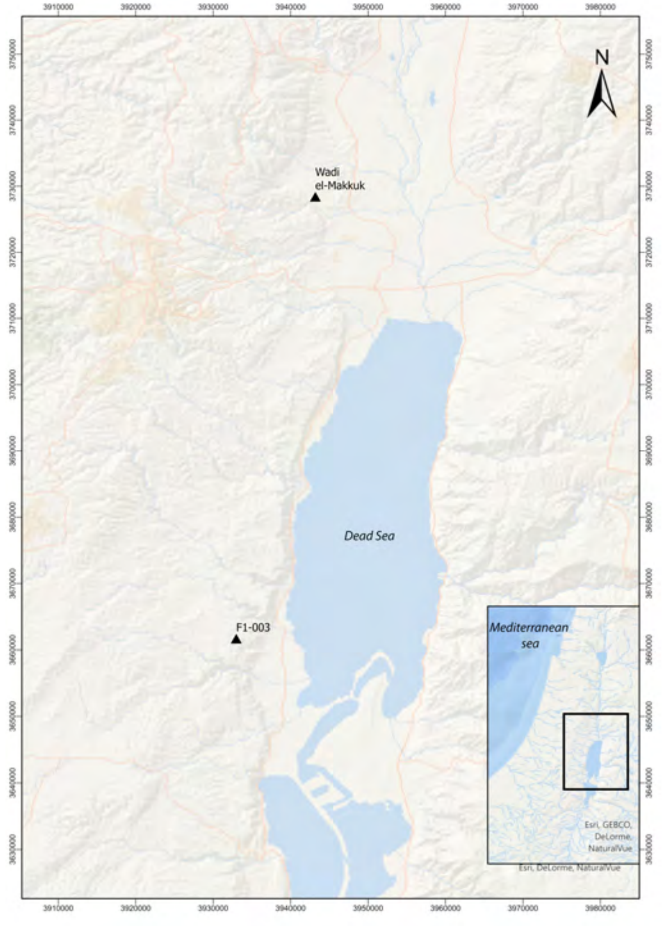

Figure 1. Site location. Drawing by Atalya Fadida, using Esri Arcmap.

& Getzov 2014, Yaroshevich 2016; Elad et al. 2018, 2019; Khalaily & Vardi 2019). Although research on this material is still in the progress (e.g., Chavoinik 2022; Kuperman, forthcoming), it is possible to determine that most of the adult burials are singular, primary ones, and jars or parts of jars were used for burying infants (e.g., Arensburg 1970; Lepetit 2017). Yet, in terms of skeletal biology, most of the osteological material is fragmented, hindering bioarchaeological study.

In 2018, as part of a large survey of the Judean Desert caves, well preserved human skeletal remains were found in cave F1-003, which had previously been visited by grave robbers. The cave is located in the hills overlooking the northern bank of Nahal

Figure 2. Nahal Mishmar, Cave F1-003. Photograph by Hagay Hamer.

Mishmar (**Figures 1**, **2**), a dry wadi west of the central area of the Dead Sea, near the well-known Cave of the Treasure (Bar-Adon 1980). The bones were found piled up in the center of the cave (**Figure 3a**), in a shallow pit that was ca. 45×40cm in size (**Figure 3b**). In addition, several flat, broken stones were found around and over the burial. Signs of past grave robbing may explain the broken stones, and the fact that some of the skeletal remains (mostly the lower extremities) were found in a pile made by the looters. Beads, a preform of a stone adze, and remains of basketry and rope were

Figure 3. (a) The bones in situ; (b) the pit grave. Photograph by Hagay Hamer.

also found along with the skeletal remains within the pit (Amichay et al. 2023). The skeleton has been roughly dated to the Late Pottery Neolithic / Early Chalcolithic. Within this period are three cultural phases referred to as the Late Wadi Rabah by Gopher (2012), the Early Chalcolithic II by Getzov et al. (2009), or simply the Early Chalcolithic by Garfinkel (1999). Due to the lack of pottery from this cave we could not relate this individual to a specific sub-period (see also Gilead 2009).

The following is a primary study, describing the biological characteristics of this skeleton, with morphometric comparison to the earlier- and later-period populations, using classic and novel methodologies of biological anthropology.

Materials and methods

C14 dating

Two types of material from the cave, an artefact (rope RTD 9671) directly associated with the skeletal remains, and a skeletal element from the skeleton (RTD 9670), were sampled for radiocarbon dating. Both samples were analyzed for their composition, presence of contaminants, and prepared for radiocarbon dating at the Dangoor Research Accelerator Mass Spectrometer laboratory of the Weizmann Institute in Rehovot, Israel (Regev et al. 2017). Chemical pre-treatment to remove contamination and extract pure cellulose from the rope and collagen from the bone follow the procedures described by Ehrlich et al. (2017) and Boaretto et al. (2009).

Sex assessment

Sex was estimated using a combination of descriptive and quantitative indicators, which included skull and pelvic morphology (Bass 2005), mandibular morphology (Loth & Henneberg 1996), and the size (vertical diameter) of the proximal head of the femur (Bass 2005).

Age-at-death estimation

Age-at-death was estimated using a combination of skeletal markers from the cranial and postcranial skeleton. These included suture closure in the cranial vault and the maxilla (Mann et al. 1987; Meindl & Lovejoy 1985), tooth attrition stages (Brothwell 1989; Li & Ji 1995), osteophyte growth in the vertebral column (Bass 2005), and chronological changes in the pubic symphysis and the auricular surface (Brooks & Suchey 1990; Lovejoy et al. 1985).

Table 1. Definition of landmarks used for capturing the three-dimensional shape of the hemi-mandible.

No	Landmark	Definition
1	Gnathion	The inferiormost point of the mandibular body in the midsagittal plane
2	Infradentale anterior	The anteriormost point of the mandibular alveolar border in the midsagittal plane
3	C–P3	The anteriormost point between the canine and the 1st premolar
4	P4–M1	The anteriormost point between the 2nd premolar and the 1st molar
5	M1–M2	The anteriormost point between the 1st and 2nd molars
6	Mental foramen	The anteriormost point of mental foramen
7	Root of ramus	The anteriormost point of the ramus rim at the level of the alveolar ridge
8	Gonion	The point on the projection of the bisection of the mandibular angle
9	Lateral condyle	From a superior view, the lateralmost point of the condyle
10	Center of condyle	From a superior view, the central point of the condyle
11	Sigmoid notch	The inferiormost point of the mandibular notch, when the mandible is positioned in the mandibular plane
12	Coronion	The superiormost point of the coronoid process
13	Mandibular foramen	The inferiormost point of the mandibular foramen
14	Alveolar process – lingual aspect	From a superior view, the intersection between a line tangent to the lingual alveolar process of the molar teeth and a line perpendicular to it, passing through the ramus root
15	Anterior condyle	The anterosuperior point of the mandibular notch
16	Posterior condyle	The posteriormost point of the condyle at its center

Stature

The femoral oblique length was measured using an osteometric board as part of estimating stature (Bass 2005). Stature of the individual was calculated using a well-established prediction formula, which averages populations of different ancestries and is independent of sex (Feldesman et al. 1990).

Morphology

Skull morphology was described by means of facial and cranial measurements, following a comprehensive list routinely in use by the Israel Antiquities Authority (IAA, Nagar 2011). The measurement technique followed Howells (1973), and covered the vault, facial, and skull base regions. Selected indices and angles were also calculated from the plain measures. The results were compared to a sample of 39 adult male skulls (in various degrees of preservation) from two later Chalcolithic-period sites attributed to Ghassulian culture: Peqi'in cave, in the northern Galilee, and Wadi Makkokh, in the northern Judaean desert. The data used for comparison were available from previous IAA excavations (Nagar 1998, 2013), yet similarly taken to avoid inter-observer error.

Table 2. Definition of curves and the number of semi-landmarks (sLMs) placed on the right hemi-mandible. LM – landmark (see **Table 1**).

No	Curve	Definition	sLMs
1	Mandibular body	Passing from the root of ramus (LM 7) along an oblique line to the midheight of the mandibular symphysis	4
2	Anterior rim of ramus	Passing from coronion (LM 12) to the root of the ramus (LM 7)	5
3	Inferior margin of the mandibular body	Passing from gonion (LM 8) to gnathion (LM 1)	5
4	Posterior rim of ramus	Passing from posterior condyle (LM 16) to gonion (LM 8)	5
5	Mandibular notch	Passing from anterior condyle (LM 15) to coronion (LM 12) on the superior border of the mandibular notch	5
6	Anterior symphysis	Passing from infradentale (LM 2) to the anteriormost point in the midsagittal plane	3
7	Inferior symphysis	Passing from the anteriormost point in the midsagittal plane to the genial tubercle	6
8	Posterior symphysis	Passing from the genial tubercle to the postero-superior point of the mandibular alveolar border in the midsagittal plane	3

The mandible of the individual from Nahal Mishmar was surface-scanned and its morphology was captured using a landmark-based geometric morphometrics (GM) protocol following Pokhojaev et al. (2019). Accordingly, the GM protocol included 16 landmarks and 36 semi-landmarks (sLM, representing 8 curves) (**Tables 1** and **2**) (Pokhojaev et al. 2019). Since only the left hemi-mandible of the individual from cave F1-003 was complete, it was mirrored in Amira software (v. 6.0) before placing the landmarks, curves, and sLMs. It was then compared to 10 Natufian hunter-gatherer mandibles from the Eynan/Mallaha and Hayonim cave/terrace sites (14,900–12,000 cal. BP); six Final Pre-Pottery Neolithic (early farmers) mandibles from the site of Atlit-Yam (7,400–6,150 cal. BP); and nine late Chalcolithic farmers and herders from Peqi'in cave (6,500–5,800 cal. BP). All mandibles included in this analysis were of adult individuals, both sexes included.

Results

Figure 4 is a schematic description of the skeletal inventory from Cave F1-003. It included a complete skull (**Figure 5**), a slightly fragmented mandible, and mostly complete postcranial bones representing one adult individual. Some hand and foot bones as well as vertebrae were missing. Most of the teeth in the upper jaw were missing, yet some were still in place (**Figure 6**). The available bones are well preserved, as most of the bones are intact. Despite thousands of years in the cave, the bones are still greasy, and remnants of cartilage were noticed prior to, and even after rinsing.

C14 dating

Table 3 summarizes the radiocarbon dates for two samples. The radiocarbon dates were calibrated using the IntCal20 calibration curve (Reimer et al. 2020) with OxCal4.4 software (Bronk Ramsey 2001). The Libby age (uncalibrated age BP) for the two samples is similar in the quoted standard deviation. 95% of the probability distribution of the calibrated range is between 5,300–5,070 BCE, setting the human remains and the rope in the Early Chalcolithic period.

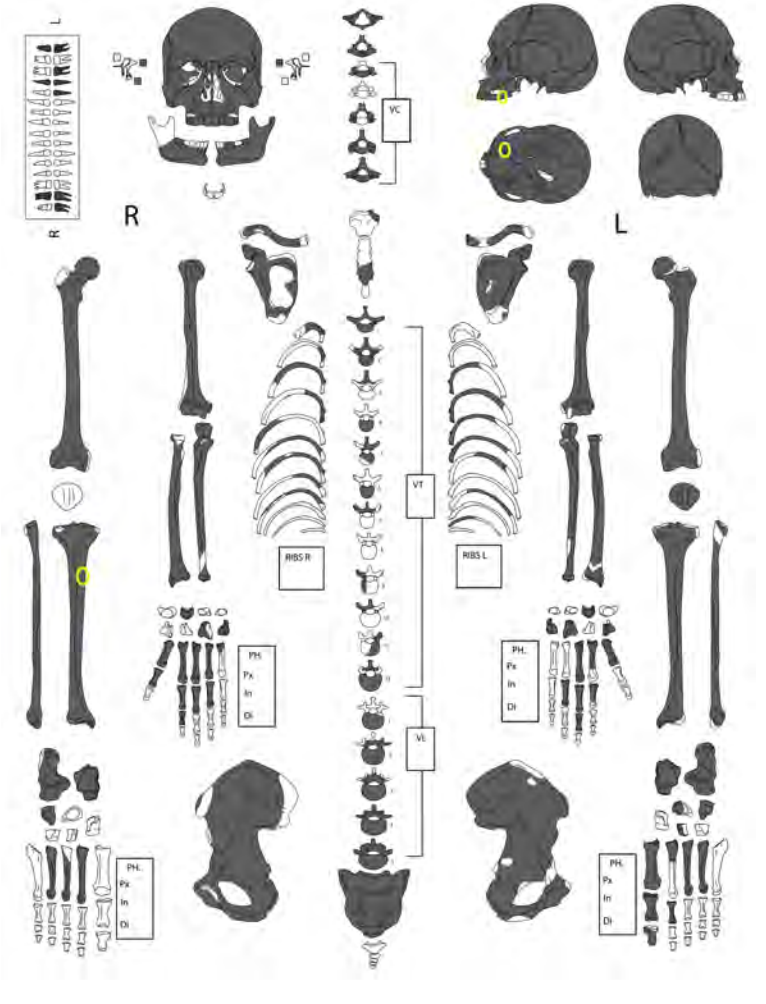

Figure 4. The skeletal inventory. Areas of pathology are indicated. Drawing by Inesse Efraimov.

Table 3. Archaeological and radiocarbon dating data for the two samples from cave F1-003. Calibrated ranges are for 68.2% ($\pm 1\sigma$) and 95.4% ($\pm 2\sigma$) using OxCal 4.4.4 (Reimer et al. 2020, Bronk Ramsey 2021).

Lab ID	Field ID	Locus	Sample	C%	Uncalib. BP	Cal. BC $\pm 1\sigma$	Cal. BC $\pm 2\sigma$
RTD 9670	B009-2	104	Bone	44.19	6213±16	5215–5070	5295–5060
RTD 9671	2018-9005	13	Rope	30.11	6232±25	5300–5080	5305–5065

Sex assessment

All aspects of sex-indicative skeletal morphology are suggestive of a male: in the skull, the glabella and supraorbital ridges are well developed, and the mastoid process and superior nuchal line are pronounced; In the mandible, the ascending ramus flexure and width, and muscle markings around the gonial angle are typical of a male. In

Figure 5. The skull. Photograph by Yossi Nagar.

the pelvis, the subpubic angle and the greater sciatic notch are relatively narrow, and the vertical diameter of the proximal head of the femur (47mm) falls within the male variation (Bass 2005; see also Nagar 2013 for femoral measurement data from a Chalcolithic local population).

Age-at-death estimation

Following criteria by Meindl and Lovejoy (1985), suture closure in the ectocranial view scored 6 in the lateral-anterior group, and 13 in the vault group, typical of the age range of 30–65 years. Although the reliability of suture closure criteria for the estimation of age-at-death was challenged by Hershkovitz et al. (1997), they still claim

Figure 6. The maxillary bone and the upper dentition. Note the advanced dental attrition, antemortem tooth loss, and an abscess in the hard palate. Photograph by Yossi Nagar.

that such advanced closure is uncommon in individuals aged less than 30 years. In the maxilla, the transverse palatine suture is completely closed. According to Mann et al. (1987), such closure may not initiate before the age of 43 years, and, as shown by Beauthier et al. (2010), being completely closed, it falls in the >50 age group in 95% of the cases. The spinal column is not complete, yet only slight lipping and no deformity or porosity is noticed in the available cervical or thoracic vertebrae. However, one lumbar vertebra shows osteophytes of about 1mm, and another vertebra shows osteophytes of over 4mm, characteristic of an individual aged >50 years (Bass 2005). In the pelvis, the auricular surface is granular without any sign of billowing. Yet, it shows no porosity, surface irregularity, or lipping of its rims, corresponding to phases V–VI of the Lovejoy et al. (1985) standards. Typical of the age range of 40–50 years, it may be stretched to 40–90 years with confidence levels of 90% (Hens & Godde 2016). Chronological changes in the pubic symphysis, corresponding to phase V of the Suchey–Brooks standards, suggest a probable age range of 40–65 years (Konigsberg et al. 2008). In the maxilla, the left second premolar and the right second molar show attrition of over half the crown's height, while in the mandible, the anterior teeth were lost post-mortem, the remaining left premolars and first molar show attrition of over half the crown's height, and the right and left third molars show dentine exposure on two cusps. Scoring the mandibular second molars only, using criteria by Li and Ji (1995), an age estimation of 70–80 years is granted; however, attrition was not even and many teeth were missing. Still, attrition as described above is considered advanced in a variety of early populations, suggesting an individual aged >50 (Brothwell 1989). Considering the skeletal markers altogether, we estimate the age of this individual to be between 50 and 65 years.

Morphology

The femoral oblique length was measured as 432mm which corresponds to a stature estimation of 162.3$\pm$3cm (Feldesman et al. 1990).

The results of the Nahal Mishmar skull measurements are presented in **Table 4**, along with the data used for comparison. No unique morphological features were noticed.

The mandible of the individual from Nahal Mishmar differed significantly from the Natufian and PPN mandibles and fell within the range of the Late Chalcolithic (**Figure 7b**). While the mandibular body demonstrated more archaic morphology, i.e., quadrangular in shape, the ramus, coronoid, and chin demonstrated a morphology that characterizes later populations. The ramus and coronoid were elongated and narrow and the coronoid slightly exceeded the condyle. The chin was more prominent compared to archaic populations (**Figure 7a**).

Table 4. Skull measurements and indices (in mm).

Measurement	Nahal Mishmar	Chalcolithic sample (n=39) min.	max.	mean	SD
Maximum length	179.0	175.0	198.0	185.8	5.9
Maximum breadth	135.0	132.0	152.0	141.1	4.2
Cranial index	75.4	70.6	80.7	75.9	2.9
Cranial module index	147.0	146.3	160.0	153.8	4.1
Mean height index	80.9	75.2	93.0	82.8	4.0
Vault height index	88.2	80.3	88.0	84.9	2.3
Frontoparietal index	62.2	61.9	76.1	66.6	3.2
Bregma angle (Na-Ba)	47.3	43.2	51.4	47.3	2.5
Frontal angle	133.0	121.0	134.0	129.1	3.2
Parietal angle	132.0	119.0	143.0	132.6	4.8
Occipital angle	112.0	111.0	131.0	120.1	5.4
Upper facial height	71.0	59.0	74.0	67.4	4.3
Upper facial index (1)	54.2	48.0	57.0	52.5	2.7
Upper facial index (2)	55.9	44.7	53.4	50.2	3.0
Orbital index	87.8	69.2	92.3	79.3	5.7
Interorbital br. index	22.2	18.3	27.3	21.7	2.5
Eye size index	54.2	49.3	59.3	54.8	2.8
Cheek height index	35.2	29.0	38.6	33.6	3.2
Nasal index	43.4	38.9	58.1	48.4	5.3
Maxillofrontal index	40.0	27.3	52.6	38.4	6.8
Zygomaxillary angle	131.0	119.0	135.0	125.5	4.2
Biauricular breadth	113.0	107.0	125.0	118.4	5.3
Palatine index	77.8	61.7	109.1	80.7	10.8
Basion angle (nasion-prosthion)	44.6	36.8	43.1	40.3	1.7
Foramen magnum ind.	87.5	77.1	100.0	87.1	6.8

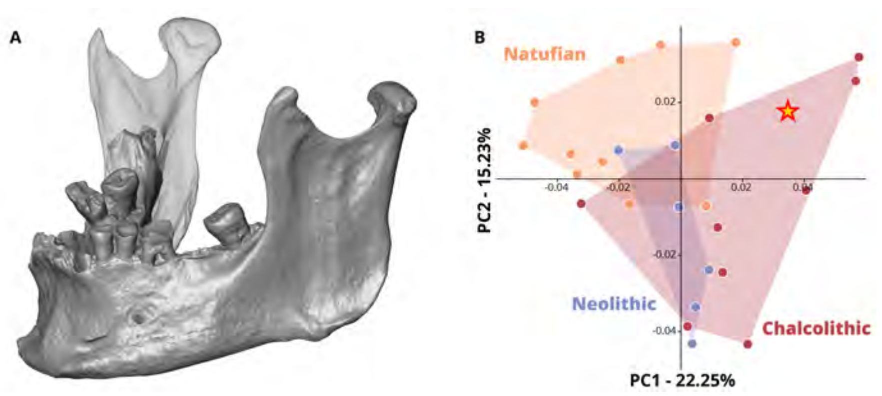

Figure 7. Morphological comparison of the Nahal Mishmar mandible with previous and succeeding-period populations. Drawing by Hilla May.

Pathology

In the maxillae, the right first premolar, the left first premolar and first molar were lost antemortem, and the alveolar bone was absorbed. In addition, two bone abscesses were observed on the left maxilla. Near the root of the first molar, a periapical cyst (10×12mm) penetrated the hard palate (**Figure 8**), while another (6×8mm) penetrated the outer alveolar bone, near the root of the first premolar (**Figure 5**). In addition, bone resorption was noticed in the mandibular body and ramus which may have been caused by osteoporosis (etiology unknown) or due to antemortem tooth loss that changed the pattern of mastication loading (Ozturk et al. 2013).

A smooth oval bulge (ca. 4×3cm) of slightly porous bone was observed in the proximal third of the medial aspect of the right tibia, with no sign of deformity or

Figure 8. Cyst in the maxilla. Photograph by Yossi Nagar.

active periostitis (**Figure 9a**). A CT cross section of the pathological area (**Figure 9b**) revealed no fracture line. No other signs of trauma or periostitis were recognized in the other long bones.

Figure 9. Modification due to trauma in the proximal third of the right tibia. (A) The outer surface of the bone; (B) CT scan cross-section. Photographs by Yossi Nagar and Hilla May.

Discussion

The human bones from Cave F1-003 in Nahal Mishmar represent one adult individual. Although some small bones were missing, the available skeletal remains were well preserved. Complete bones in a similar state of preservation (bearing soft tissue), have also been reported from the 4th millennium BC 'Cave of the Warrior' skeleton in nearby Wadi Makkukh cave (Nagar 1998), stressing the effect of the unique climate of the Judaean Desert caves on taphonomy in the present case.

Due to unfortunate constraints, the skeletal remains were not checked by an anthropologist *in situ*, and thus, the burial description must be considered with caution. The position of the bones, however, and the fact that they were placed in a shallow pit (its dimensions were too small to accommodate an articulated skeleton), suggest a secondary burial. This is also supported by the absence of several carpal bones, phalanges, and vertebrae, which may have lost in the process of relocation. Unlike the Neolithic period, secondary burial was the norm during the Late Chalcolithic (Ghassulian) period. Hence, let alone the extensive use of ossuaries, a secondary burial in the Early Chalcolithic is in accordance with the burial practices of the forthcoming Ghassulian culture (Amichay et al. 2023).

The skull, mandibular, and pelvic morphology are typical of a male. Age-at-death, based on skull, dental, and postcranial markers, is estimated as 50–65 years. The individual's estimated stature, 162cm, is similar to the average stature reported for other Chalcolithic period populations (163cm; Nagar 2013), and also to the later, Hellenistic period populations of the Dead Sea region (162cm; Arensburg et al. 1980).

This individual suffered from some ante-mortem tooth loss in both upper and lower dentition, which led to infection. Although most teeth were lost post mortem, advanced carious lesions, in at least three teeth in the maxilla and one tooth in the mandible, were evident not only by tooth loss, but also by two cases of periapical cysts in the maxillary bone. The aforementioned penetrated through the outer alveolar bone, and an abscess was noted on the left side of the hard palate. Abscessing following dental caries was present in 5%–10% of the adult population during the Chalcolithic period, and its frequency roughly correlated with age (Lev-Tov et al. 2003). Although common, it was undoubtedly a painful situation which affected the individual's well-being. Moreover, such infection may have led to the individual's death (Burczyńska et al. 2017). A small bulge in the proximal outer surface of the tibial diaphysis is possibly the result of a direct hit at this area that did not fracture the bone (Merbs 1989), but resulted in an inflammatory process that provoked small-scale remodeling at its outer surface.

In order to assess the morphological similarity between the Nahal Mishmar skull and the reference, Chalcolithic period population, the difference in each measurement or index between the Nahal Mishmar skull and the reference population was calculated as a function of distance expressed by units of standard deviation (SD). As can be seen in **Table 4**, most of the Nahal Mishmar results fluctuate around the Chalcolithic mean, with only one trait (palatine index) deviating more than two SD units. Since palatine morphology is prone to changes due to tooth loss and alveolar bone absorption, the small difference noticed in palatine index could be age-related.

The morphology of the skull and mandible is also suggestive of mastication loading which is known to be related to diet abrasiveness (Sella Tunis et al. 2018, Toro-Ibacache 2016). Since the morphology of the skull and mandible of the individual from Nahal Mishmar fell within the Chalcolithic variation, it may suggest similarity in terms of dietary aspects. Nevertheless, the pathological condition of the mandible, as well as a combination of morphological characteristics, some of which are more archaic, while others are similar to those of later populations (e.g., Roman-Byzantine ones), should be taken into consideration. The elongated ramus and coronoid and prominent chin might be a result of ante-mortem tooth loss, which changed the forces that were applied to the mandible, as well as of bone resorption that appeared on both the anterior part of the mandibular body and the ramus. It is noteworthy that our inability to estimate the sex of the reference sample used for the shape analysis of the mandible did not bias or had only a minor effect on our results as the individual from Nahal Mishmar who was estimated as a male fell within the Chalcolithic variation and not within the variation of the Natufians.

The origin of the Chalcolithic populations of the Levant is of major interest. Therefore, despite the morphological similarity between the Nahal Mishmar skeleton and the later, Ghassulian Chalcolithic populations, as suggested above, further genetic study is required on the populations of the Early and Late Chalcolithic periods to decipher their origin, and to examine the relations between the Judean desert and the northern population of Israel at that time.

Human presence in this period in the Judean desert hills in general, and in the specific vicinity of Nahal Mishmar is evident, however, finding a skeleton alone in a cave with no other contemporary burials known in this area, needs further consideration. Pottery and objects dated roughly to the period of the burial in Cave F1-003 were found in a rift ('Amnon's Cave) north of Nahal Mishmar. These included pottery and a mat dated to ca. 5,600-5,400 cal. BC (Dahari 2002). Other contemporary remains were found in the caves of Wadi Muraba'at (Benoit et al. 1961, Garfinkel 1999), with pottery sherds of the Wadi Rabah culture. Since no settlements from this time are known in the vicinity, suggesting a scenario explaining such a secondary burial in the Nahal Mishmar cave would be just a matter of speculation for now.

Conclusions

The bones of one individual, dated to the Late Pottery Neolithic (Early Chalcolithic) period, were found in Cave F1-003 at Nahal Mishmar, probably representing an old (50–65 years) male individual. Such an old male could have been a distinguished person in this prehistoric society, where life expectancy was around 30 years, and only about 10% of the adults exceeded the age of 50 (Lev-tov et al. 2006, Nagar 2013). Indeed, he received a 'respectful' and unique burial.

The well preserved skeletal remains manifested cranial and mandibular morphological similarity to the succeeding Late Chalcolithic period populations. The individual suffered from massive tooth loss, and abscesses of the maxilla. A direct hit at the medial aspect of the right tibia resulted in an inflammatory process that provoked small-scale remodeling at its outer surface.

Future studies would include advanced biological research (using aDNA), to verify or refute the above hypothesis of population continuity from the Early to the Late Chalcolithic, aimed at understanding the unique phenomenon of secondary burial of one man alone in a cave in the desert, in an era prior to the advent of the classical Ghassulian culture cemeteries.

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