

# A craniometric analysis of early modern Romania and Hungary: The roles of migration and conversion in shaping European Ottoman population history

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## Abstract

**Objectives:** Debate persists regarding the biological makeup of European Ottoman communities settled during the expansion of the Ottoman Empire during the 16th and 17th centuries, and the roles of conversion and migration in shaping demography and population history. The aim of this study was to perform an assessment of the biological affinities of three European Ottoman series based on craniometric data.

**Materials and Methods:** Craniometric data collected from three Ottoman series from Hungary and Romania were compared to European and Anatolian comparative series, selected to represent biological affinity representative of historically recorded migration and conversion influences. Sex-separated samples were analyzed using  $D^2$ -matrices, along with principal coordinates and PERMANOVA analyses to investigate biological affinities. Discriminant function analysis was employed to assign Ottoman individuals to two potential classes: European or Anatolian.

**Results:** Affinity analyses show larger than expected biological differences between males and females within each of the Ottoman communities. Discriminant function analyses show that the majority of Ottoman individuals could be classified as either European or Anatolian with a high probability. Moreover, location within Europe proved influential, as the Ottomans from a location of more geopolitical importance (Budapest) diverged from more hinterland communities in terms of biological affinity patterns.

**Discussion:** The results suggest that male and female Ottomans may possess distinct population histories, with males and females divergent from each other in terms of their biological affinities. The Ottoman communities appear diverse in terms of constituting a mix of peoples from different biological backgrounds. The greater distances between sexes from the same community, and the differences between communities, may be evidence that the processes of migration and conversion impacted individual people and groups diversely.

## KEYWORDS

biological distance, craniometrics, Ottoman, population history, Southeast Europe

## 1 | INTRODUCTION

History has been significantly marked by the rise and fall of great empires. Similar to most historic political powers, the Ottoman Empire had a significant impact on the world (Brown, 1996; Firges, Graf, Roth, & Tulasoglu, 2014; Fromkin, 2001). Lasting for over 600 years (14th to early 20th century), this empire is considered by many to be one of the

most influential Muslim political powers in history (Brown 1996, p. 4). At their greatest extent, the Ottomans controlled most of the modern Middle East, northern Africa, and southeastern Europe (Woodhead 2012, p. 1). As is common in the history of empires that spanned varied lands, different regions formerly part of the Ottoman territory were impacted in diverse ways. A central aspect of the Ottoman legacy, often overlooked and simplified, was its interregional variability (Brown

1996, p. 54). Southeast Europe is unique from other regions of Europe, in part due to its inclusion in the Islamic empire, and has a distinctive history as a result of the brief but dynamic Ottoman period.

There are longstanding debates regarding the histories and identities of the Muslim communities that settled in Southeast Europe during the Ottoman period (Kirmizialtin, 2007; Todorova and Todorova, 1992; Zhelyazkova, 2002). As with any political expansion, individuals from Anatolia—the capital region of the empire—were likely to have migrated to newly acquired areas, as soldiers, administrators, and political leaders. The Ottomans were known to have state policy that actively encouraged movement; for example, at times, entire communities were forced to relocate as punishment or a means of settling recently conquered regions (Kasaba, 2012), and some historic interpretations detail population replacements by incoming Ottomans from other parts of the empire (Sugar, 1977). A mass migration of people is, however, not the only process that may have defined the Ottoman communities in Southeast Europe. Written records from this time period also record the conversion of Europeans to Islam for a variety of reasons, some forced, others voluntary. These records have been analyzed by historians studying the causes and consequences of conversion processes transforming Europeans into Islamic Ottomans (Ágoston, 2009; Baer, 2004; Graf, 2014; Kirmizialtin, 2007; Zhelyazkova, 2002), but a consensus on the extent to which different migration and conversion practices influenced the biological makeup of European Ottoman communities has not been reached. For example, while some reports detail how different conversion or migration processes impacted males or females specifically (e.g., Ágoston, 2009; Baer, 2004), the diverse experiences and biological backgrounds found between sexes within individual Ottoman communities around Europe are rarely discussed. Similarly, how these processes influenced different areas diversely can be difficult to assess. The demography of politically important locations, such as the European capital centers of Buda and Pest, are reported by some historical interpretations as severely impacted under Ottoman rule. Some historical accounts relay a large population shift, those living in this capital region departing suddenly with a population exodus and replacement by Ottoman officials (e.g., Sugar, 1977, p. 71), with these politically important centers frequently described as densely packed with soldiers (Hegyí, 2000). Whether or not such extreme population replacement is accurate, and the extent of similar processes of change in smaller towns around the Ottoman territory is not always readable via historic texts however. How diverse migration and conversion trends influenced different demographic groups internally, as well as different communities in locations of diverse geopolitical importance, are important considerations not fully understood from historiography alone.

In this research, we adopt a multivariate craniometric approach to test specific hypotheses regarding the population history of three Ottoman sites in Southeast Europe. Quantitative craniometric data have repeatedly been shown to follow a largely neutral model of microevolutionary change predominantly affected by mutation, gene flow, and genetic drift (e.g., Roseman, 2004; von Cramon-Taubadel, 2014). As such, craniometric data are routinely employed as a reliable proxy for

neutral genetic data in analyses of modern and archaeological skeletal samples (Buzon, 2006; Herrera, Hanihara, & Godde, 2014; Hubbe, Harvati, & Neves, 2011; Pinhasi and von Cramon-Taubadel, 2009; Strauss and Hubbe, 2010; von Cramon-Taubadel, Stock, & Pinhasi, 2013). Here, craniometric analyses were utilized to analyze the population histories of three 16th and 17th century Ottoman communities that lived in areas that today are part of Romania and Hungary. Two of these communities issue from more rural or hinterland locations in the Ottomans' European territory, while one issues from the more geopolitically important city of Pest. Biological distance (biodistance) and classificatory analyses were employed to explore the affinities of these three Ottoman groups relative to comparative samples from Anatolian and non-Ottoman European contexts. These comparative series were selected based on historic interpretations of the potential biological origins of Ottomans who either migrated into Europe or Europeans who converted to Islam and consequently became a part of the Ottoman community. Moreover, to test for discrepancies between the sexes and communities of different political and geographic locales, we compared the affinities of males and females separately from each Ottoman group, as well as tested how communities from different parts of the Ottoman's European territory compared with each other.

Specifically, this study aims to address the following questions: (1) Do the three Ottoman communities share greater biological (craniometric) affinity with local European or with Anatolian groups, or do they display a population affinity distinct from these comparative groups? (2) Do male and female Ottomans display the same affinity patterns, suggesting a common biological origin or are there distinct differences between them, when compared with European and Anatolian groups? (3) Are there systematic differences in the biological affinities of the two hinterland Ottoman communities compared with the politically central Ottoman group?

## 2 | MATERIALS AND METHODS

### 2.1 | Cranial series

Six different skeletal series were sampled from collections currently curated by four institutions in three countries (Table 1). Three of the collections include individuals from 16th and 17th century Ottoman populations buried within the modern borders of Romania and Hungary. Additionally, three comparative populations were employed: two Medieval/Early Modern European groups (Zalávar and Berg), and an Anatolian skeletal series including individuals from Adalia, Turkey (now Antalya) and Aleppo, Syria (Figure 1). In all series, the metric data were collected by KG Allen with two exceptions. The Zalávar and Berg data were taken from the craniometric dataset collated by W.W. Howells (1973, 1996). Interobserver error between the series measured by the author and those by Howells was mitigated with an initial remeasuring of a sample of Howells's data, described in more detail below.

#### 2.1.1 | Ottoman collections

Three skeletal collections with individuals from Ottoman burial contexts were used to represent the Ottoman communities in the region

TABLE 1 Description of six skeletal series utilized in this research

Skeletal series	Time period	Museum in custody of series	Location of collection	Males (n)	Females (n)
Timișoara (TIMI)	Ottoman	Muzeul Național al Banatului Timișoara (National Museum of Banat, Timișoara)	Timișoara, Romania	14	12
Dombóvár-Békató (DB)	Ottoman	Wosinsky Mór Megyei Múzeum (Wosinsky Mór County Museum)	Szekszárd, Hungary	13	18
József Nádor Tér (JNT)	Ottoman	Magyar Természettudományi Múzeum (Hungarian Natural History Museum)	Budapest, Hungary	13	12
Zalávar	Medieval	Magyar Természettudományi Múzeum (Hungarian Natural History Museum)	Budapest, Hungary	20	20
Berg	Early Modern	American Museum of Natural History	New York City, USA	15	15
Anatolian	Various	American Museum of Natural History	New York City, USA	19	12

in the 16th and 17th centuries. While the cemeteries differ from each other in a number of ways, historic and archaeological evidence indicate their involvement in the Ottoman administration and governance of the region, and they are geographically and culturally set apart from the local populations that inhabited the region prior to and during the transition to Ottoman political control. The first Ottoman collection comes from the city of Timișoara ("TIMI") in western Romania, and consists of individuals found in an Ottoman cemetery excavated by the National Museum of Banat, Timișoara. The city of Timișoara served as an Ottoman garrison for over 150 years and was located on an eastern border of the empire's European territory. The burials were found adjacent to the remnants of one of the former Ottoman garrison town

mosques and were buried in a manner congruent with Islamic burial tradition (Drașovean et al., 2007). The second Ottoman series, the Dombóvár-Békató collection (DB), consists of human remains from a non-Christian population from Ottoman conquered territory near the settlement of Békató and the Dombó fortress in Hungary (Gaal, 2003). Currently archived at the The Wosinsky Mór County Museum in the city of Szekszárd, this group was originally thought to represent Turkish vassals of a potentially European origin (Gaal, 2003; Kinga, 1982; Wicker, 2008). The archaeological burial characteristics described are indicative of Islamic burial traditions; for example, grave orientation, the absence of coffins, the covering of the body with wooden planks, and the description of the two main grave morphologies, which

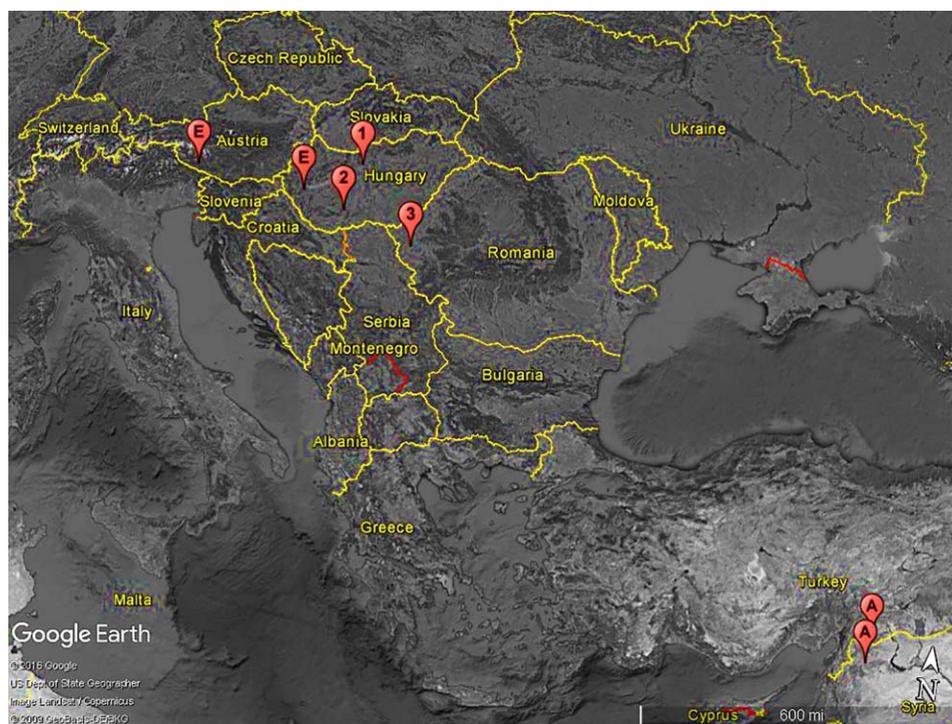


FIGURE 1 Map depicting population contexts. Markers labeled with E (European) and A (Anatolian) depict the locations associated with the comparative populations. The three numbered markers highlight the contexts of the Ottoman groups (1, József Nádor Tér [JNT]; 2, Dombóvár-Békató [DB]; 3, Timișoara [TIMI])

resemble the traditional Islamic burial pits (*shiqq* and *lahd*) match archaeological burial traditions found in the Islamic world (Petersen, 2013). Similarly, the historic timeline indicates that the nearby community of Békátó was under Ottoman control at the time of the cemetery's use (Gaal, 2003). Last, the József Nádor Tér Ottoman sample (JNT) comes from a recently excavated Ottoman cemetery discovered at the end of May 2016 and currently housed at the Hungarian Natural History Museum. The remains were excavated from the square the series is named after, on the Pest side of Budapest. The cemetery was used in the 17th century and the burial contexts indicate an Islamic Ottoman cemetery (Toth, *forthcoming*; Toth, pers comm). These three cemeteries represent three distinct communities that settled in Romanian and Hungarian lands during the brief but dynamic Ottoman period.

### 2.1.2 | Comparative collections

Two European populations from Howell's (1996) craniometric database (the Zalávar and the Berg) were utilized to create a European comparative sample from the same general geographic area, designed to create a model of craniometric affinity if conversion of Europeans to Islam was a major factor in creating these Ottoman communities. The Zalávar collection consists of individuals buried between the 9th and 11th centuries in central Hungary, currently housed at the Hungarian Natural History Museum. While the Zalávar collection is quite substantial, with 944 individuals from four different cemeteries of varying contexts in and around the village of Zalavár (Acsadi, Harsanyi, & Nemeskeri, 1962; Howells, 1973), only individuals included in the Howells database were utilized. Of the four cemeteries, cranial measurements of individuals from two main contexts were included in the Howells' database: the Zalavár Castle and the Zalavár Chapel (Howells', 1973). The Zalavár Chapel housed a homogenous group of people described as the "ancient inhabitants." The castle on the other hand, was a heterogeneous mix of individuals, including Avars, Romanized Germans and Slavs, members of the Frankish Court, Church and Army, and Hungarians (Magyars) (Acsadi et al., 1962; Howells, 1973).

The second European collection, Berg, comes from a small mountain village near Greifenburg, Austria in the western part of the Carinthian province. The collection, housed in the Anthropology Department at the American Museum of Natural History (AMNH) in New York City, was collected by Felix Von Luschan in the 1920s from a charnel house (Howells, 1973; Shapiro, 1929). The population of this village was largely isolated and the collection is thought to represent five generations of the village's inhabitants buried between the 17th and 19th centuries (Howells, 1973).

In addition to the two European populations, a series representing individuals from Anatolia was employed. This comparative population represented potential craniometric affinity if the migration of non-Europeans from the Ottoman heartland was an important factor in creating the three Ottoman communities under investigation. A collection of crania from mixed contexts from Anatolia are housed in the Anthropology Department of the AMNH. The collection labelled "Turkish" includes Aintab (today called Gaziantep) and Adalia individuals, as well as crania listed as "Kurds," "Armenians," and "Mohammedans" (an

antiquated term for a Muslim). Additionally, a series of crania from Aleppo, Syria is housed at the museum. Both the Turkish and Syrian collections were donated by Felix Von Luschan, an avid collector of human remains in the 18th and early 19th century. The description of the group of individuals analyzed here is as follows: two individuals listed as "Kurds" from Aintab (Gaziantep), a city in southeastern Turkey near the Syrian border; twelve individuals labelled as "Mohammedan," also from Aintab; two Armenian individuals, also from Aintab; three individuals labelled as "Assar-Önü Lycian Asia Minor-Turkey," presumably referencing Lycia, an old geopolitical term for a region that today includes the Antalya and Muğla provinces in southern Turkey; 13 individuals from a graveyard in Aleppo, Syria a city geographically proximate to Aintab and the location of one of the Ottoman Empire's largest cities.

### 2.2 | Selection of individuals

The goal was to obtain data from 20 to 30 predominantly complete adult crania with sufficient representation from both sexes. Adult age was ascertained by noting the fusion of the spheno-occipital synchondrosis, which normally occurs between 18 and 25 years of age (White, Black, & Folkens, 2012). This is a common point at which an individual is considered an adult in terms of skeletal biology (Scheuer and Black, 2000). In some individuals, this region of the cranium was either missing or badly fragmented. In these cases, other indicators of adult age, predominantly fused medial epicondyles of the clavicles, were used. The medial clavicle, one of the last bone epiphyses to fuse, will display an epiphysis that spreads over most of the medial surface between 24 and 29 years and will be completely fused by 30 years (Scheuer and Black, 2000). This allowed for the determination of adult age in the remains that had postcranial material readily accessible.

Sex of each cranium was assessed based on standard macroscopic features such as nuchal crests, mastoid processes, supraorbital margins, glabella, and mental eminences (Buikstra and Ubelaker, 1994). When possible or necessary, os coxae were used to assist in estimation of sex, based on visual inspection of sexually dimorphic characters such as ventral arcs, sub public concavity, ischiopubic rami ridges, greater sciatic notches, and pre-auricular sulci. In cases where individuals were ambiguous in terms of their biological sex indicators, those individuals were not utilized for the sex-specific analyses.

### 2.3 | Interobserver error

Table 2 shows the 32 craniometric measurements used in this study. Measurement protocols and definitions follow Howells (1973). Prior to data collection from skeletal series housed in Timișoara, Szekszárd, Budapest, and New York, an intraobserver exercise was conducted by KG Allen using eight skulls from the Berg collection, housed at the AMNH. After recording the measurements, they were checked against Howells' data. This effort ensured that the measurements were taken the same way by both researchers. For measurements that were more than 1 mm off from Howells' measurements, the manner in how the measure was taken was scrutinized. If too much error (>10% of the

TABLE 2 Howells' measurements employed

Measurement	Description	Measurement	Description
GOL	Glabello-Occipital Length	MDB	Mastoid Width
BNL	Basion-Nasion Length	ZMB	Bimaxillary Breadth
BBH	Basion-Bregma Height	FMB	Bifrontal Breadth
XCB	Maximum Cranial Breadth	NAS	Nasio-frontal Subtense
XFB	Maximum Frontal Breadth	DKB	Interorbital Breadth
STB	Bistephanic Breadth	WNB	Simotic Chord
AUB	Biauricular Breadth	IML	Malar Length Inferior
WCB	Minimum Cranial Breadth	XML	Malar Length Maximum
ASB	Biasterionic Breadth	WMH	Cheek Height
NLH	Nasal Height	FOL	Foramen Magnum Length
OBH	Orbit Height Left	FRC	Nasion-Bregma Chord
OBB	Orbit Breadth Left	FRS	Nasion-Bregma Subtense
JUB	Bijugal Breadth	PAC	Bregma-Lambda Chord
NLB	Nasal Breadth	PAS	Bregma-Lambda Subtense
MAB	Palate Breadth	OCC	Lambda-Opisthion Chord
MDH	Mastoid Height	OCS	Lambda-Opisthion Subtense

mean) was apparent, that measurement was removed from the set of measurements utilized thereafter. A final set of 32 easily replicated measurements that were reasonably well represented across fragmentary archaeological collections were collected.

## 2.4 | Missing data estimation and size adjustment

Missing data were estimated using multiple linear regression interpolation by sample in SPSS v. 23. Individuals with more than 50% missing data were removed from the dataset. The overall percentage of measurements that were missing and required interpolation was 4.3% (Supporting Information, Table S1). Once original and interpolated measurements were combined, the dataset was adjusted for isometric scaling variation by dividing each variable or measurement by the geometric mean of all measurements for that individual, creating scale-free

shape variables (Falsetti, Jungers, & Cole, 1993; Jungers, Falsetti, & Wall, 1995).

## 2.5 | Statistical methods

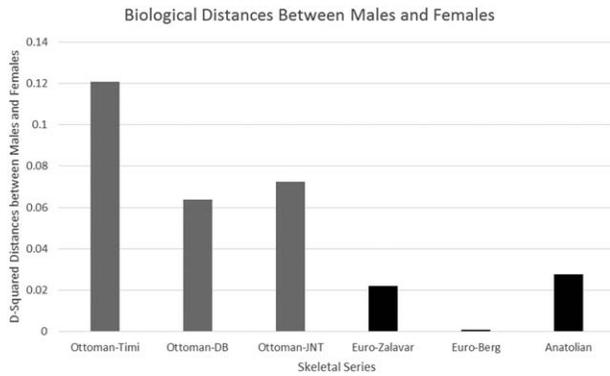
The final data set was composed of 183 individuals from the three Ottoman and three comparative (European and Anatolian) collections (Table 1).

The Relethford–Blangero multivariate extension of the Harpending–Ward model (Harpending and Ward, 1982; Relethford and Blangero, 1990) was employed to calculate  $D^2$ -matrices under assumptions of complete trait heritability ( $h^2 = 1$ ). The resultant biodistance matrices were generated in the freeware RMET separately for males and females. Thereafter, one  $D^2$ -matrix was generated for 12 samples representing males and females from each of the six cranial series. These

TABLE 3  $D^2$  matrix showing biological distances between populations for males (upper triangle) and females (lower triangle)

	Ottoman populations			Comparative populations		
	TIMI	DB	JNT	ANATOLIAN	ZALAVÁR	BERG
TIMI	0	0.0688	0.1769	<b>0.2126</b>	0.3056	0.2656
DB	0.1165	0	0.1295	<b>0.2417</b>	0.3143	0.2739
JNT	0.1695	0.1107	0	0.2201	0.1994	<b>0.1248</b>
ANATOLIAN	<b>0.2914</b>	0.2654	<b>0.1075</b>	0	0.2663	0.2724
ZALAVÁR	0.3046	0.2954	0.2309	0.2152	0	0.0902
BERG	0.3126	<b>0.2326</b>	0.1650	0.2731	0.0482	0

For each of the three Ottoman groups (TIMI, DB, and JNT), the shortest distance to comparative groups is highlighted in bold.



**FIGURE 2**  $D^2$  distances between sexes for all six populations, highlighting the larger biological distances between males and females in the three Ottoman populations (grey) compared to the three comparative populations (black)

$D^2$ -data were used to compute average biological distances between sexes, within-populations. Between-group differences were visualized using principal coordinates analysis (PCoA) for males and females separately. Subsequently, a Permutational Multivariate Analysis of Variance (PERMANOVA) utilizing Gower distance was employed to test for significant differences between sexes, within groups. This nonparametric alternative to MANOVA was used as the data violated parametric assumptions of normality and sample size. Discriminant Function Analysis (DFA) was then used to assign Ottoman specimens to two potential classes: European (Berg/Zalávar) and Anatolian. Ottoman individuals were unclassified and a stepwise method was employed to retrieve each Ottoman individual's posterior and typicality probabilities of being classified as either European or Anatolian. DFA were performed on the male and female data separately.

### 3 | RESULTS

#### 3.1 | Relethford–Blangero matrices

Table 3 displays the sex-specific  $D^2$ -matrices. Ottoman males from the two smaller or hinterland communities (TIMI and DB) share closer overall cranial affinities with Anatolians compared with the two European groups, while the JNT group from Budapest are on average most similar to the Berg and Zalávar. In contrast, the female Ottomans from the two hinterland groups show approximately equal distances between Anatolian and European groups, while the JNT show much shorter distance to the Anatolian sample.

When looking within each group, there is a clear distinction in overall biological distance between males and females in all three Ottoman series when compared to both the Anatolian and European comparative series (Figure 2). The comparative populations have considerably lower between-sex  $D^2$  distances when compared to the three Ottoman series. Additionally, of the three Ottoman series, the individuals from Timișoara, Romania (TIMI) show the most pronounced within-group biological distance between males and females. Conversely, the two Hungarian Ottoman communities (DB and JNT) resemble each other in relative distance, while still displaying distinctly

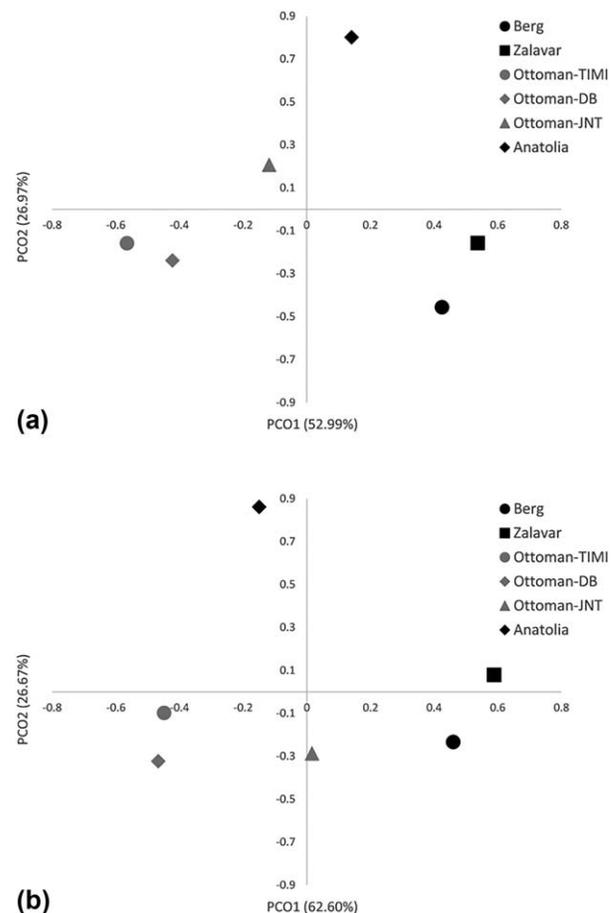
higher between-sex distances compared to the European and Anatolian groups.

#### 3.2 | PERMANOVA results

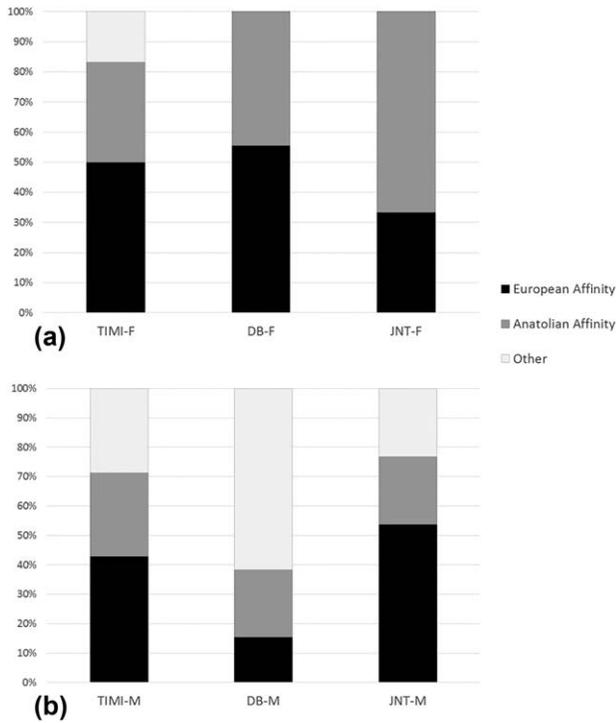
Results of the PERMANOVA test revealed significant differences between male and female samples in cranial shape for the three Ottoman populations (TIMI,  $p = .0056$ ; DB,  $p = .0256$ ; and JNT,  $p = .0038$ ), but not for the three comparative groups from Europe or Anatolia (Berg,  $p = .2876$ ; Zalávar,  $p = .0986$ ; and Anatolia,  $p = .2421$ ).

#### 3.3 | Principal coordinates analysis

The results of the PCoA analyses are displayed in Figure 3. Viewing these plots as visual representations of between-group differences, a few distinctions stand out. First, for both males and females, the Ottoman communities from the small, more hinterland, locations of the empire (TIMI and DB) are closer in biological distance to each other, while the JNT site in the geopolitically important city of Pest is divergent from the other two Ottoman groups. Second, in both the male and female PCoA plots, none of the three Ottoman samples share close affinity overall to any comparative population. Last, when noting the



**FIGURE 3** Plot of the first two principal coordinates showing the between-groups affinity pattern for the (a) female data and (b) male data



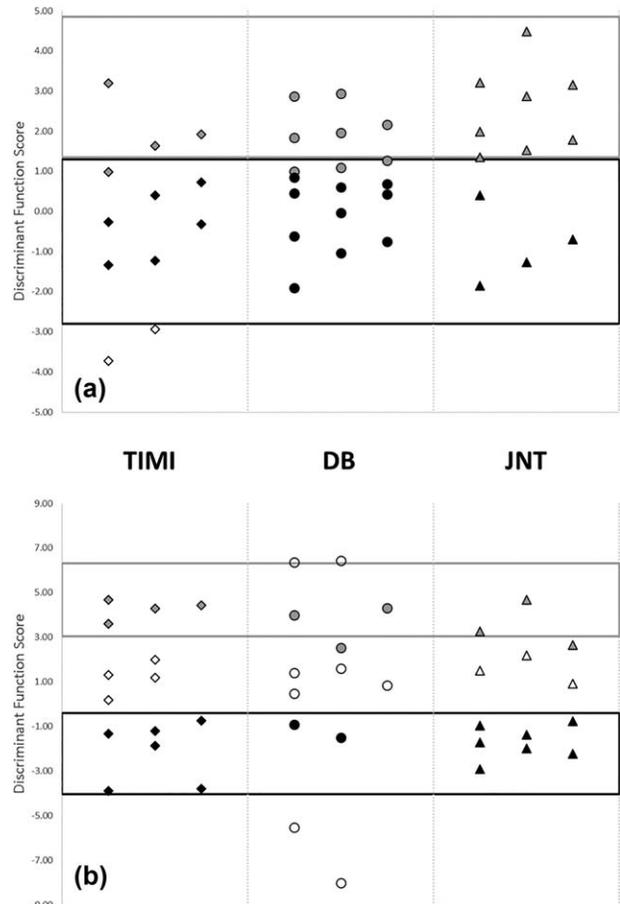
**FIGURE 4** Discriminant function analysis classification results for (a) female and (b) male individuals from all three Ottoman series expressed as a percentage of the total sample based on typicality probabilities

position of the Ottoman JNT males and females, the female sample is much closer to the Anatolian comparative sample, as compared to the males.

### 3.4 | Discriminant function analysis

Discriminant function analyses used to classify males and females from the three Ottoman skeletal series as either European or Anatolian reveal distinct results for both sexes (Table 4 and Figures 4 and 5). Figure 4 shows the percentage of Ottoman individuals classified as European, Anatolian, or “other” according to their typicality probabilities ( $p > 0.05$ ). In the case of the female Ottomans (Figure 4a) nearly all individuals could be classified as either European or Anatolian, with only two individuals from Timișoara classified as “other.” In contrast, in the case of the male Ottomans (Figure 4b), each series had a relatively high proportion of individuals who were not typical ( $p < 0.05$ ) of either the European or Anatolian reference series. In the case of JNT, a relatively large proportion of males were classified as being European, in contrast with the females where the majority were classified as Anatolian. In the case of DB, a large proportion of males could not be classified as being either European or Anatolian, which contrasted with the females where majority were classified as being European. In the case of the series from Timișoara, Romania (TIMI), females classified as European represent 50% of the sample, while males are more mixed between European, Anatolian, and “other.”

To provide further context for these initial classification results based on typicality probabilities, Figure 5 shows the individual



**FIGURE 5** Plot of Ottoman specimens' discriminant function (DF) scores relative to the reference DF scores (y-axis) for (a) females and (b) males. In each panel, the upper grey box = range of DF scores for the Anatolian reference sample, lower black box = range of DF scores for the European reference sample. The three Ottoman groups (TIMI, diamonds; DB, circles; JNT, triangles) are separated by vertical dashed lines. Each Ottoman specimen is color-coded according to its classification based on typicality probabilities (grey, Anatolian; black, European; white, Other)

**TABLE 4** Discriminant function analysis results

	European	Anatolian	Other	Total sample
Ottoman TIMI-Males	6 (43%)	4 (28.5%)	4 (28.5%)	14
Ottoman TIMI-Females	6 (50%)	4 (33%)	2 (17%)	12
Ottoman DB-Males	2 (15%)	3 (23%)	8 (62%)	13
Ottoman DB-Females	10 (55%)	8 (45%)	0 (0%)	18
Ottoman JNT-Males	7 (54%)	3 (23%)	3 (23%)	13
Ottoman JNT-Females	4 (33%)	8 (67%)	0 (0%)	12

Number of individuals (percentage of sample) from each of the three Ottoman groups classified as either European or Anatolian with typicality probabilities  $p > 0.05$  for category membership. The “other” category records individuals who did not have a strong affinity (i.e., typicality probabilities  $p < 0.05$ ) to either the European or Anatolian comparative samples.

discriminant function (DF) scores for each Ottoman specimen against the range of DF scores obtained for the European (Berg/Zalávar) and Anatolian reference samples. As there were only two groups in the DFA, DF1 explains 100% of the variance in each case. For the females, the cross-validated (leave-one-out jackknife) classification for the reference sample was 100% correct for the Anatolians, and 91.4% correct for the Europeans (three individuals were misclassified as Anatolian). In the case of males, both Anatolians and Europeans were correctly classified 100% of cases. As can be seen in Figure 5a, the DF scores for Anatolian and European females are, overall, more similar compared with the male DF scores (Figure 5b) where there is a clear separation between the Anatolian and European samples. Figure 5 overlays the DF scores for each Ottoman specimen with color-coding according to their typicality probabilities. In the case of females (Figure 5a), because the range of DF scores for Anatolians and Europeans were contiguous, almost all Ottoman specimens could be classified as being “typical” of either the European or Anatolian series, with only two Timișoara females deemed atypical of either group, falling on the extreme “European” end of the range of DF scores. In the case of males, however, a number of specimens from each Ottoman series fall between the ranges of European and Anatolian DF scores, and were, therefore, considered atypical of either group. Interestingly, the series from DB is distinct from Timișoara and JNT in having male specimens classified as “other” that fall between Europeans and Anatolians, and also fall at the extreme ends of the distribution of DF scores. Supporting Information, Table S1 also provides the full classification results for each individual, including the posterior and typicality probabilities, Mahalanobis’ distances to the predicted group, and discriminant function scores.

#### 4 | DISCUSSION

The main aims of this research were to assess whether or not the three Ottoman communities shared greater biological affinities with local European or Anatolian groups, to assess the variation between the sexes in terms of these affinity patterns, and to assess whether Ottoman communities of diverse political or geographic importance differed in their craniometric affinity with the European and Anatolian reference groups. The results of the affinity analyses (based on  $D^2$ -matrices and principal coordinates analysis) and the PERMANOVA analysis suggest that there are larger than expected biological differences between males and females within each of the three Ottoman communities. None of the comparative populations (European or Anatolian) display the same extent of between-sex variation that the Ottoman communities exhibit. Therefore, the results suggest that male and female Ottomans may possess distinct population histories, in contrast with non-Ottoman European or Anatolian groups. Visualizing the between-group affinities as principal coordinate plots reveals that the three Ottoman series are relatively distinct from both the European and the Anatolian comparative groups, although the series from the centrally-located Ottoman settlement (JNT) was overall more similar to the comparative populations than the two hinterland Ottoman groups. These results point to differences between the biological affinities of the two more

rural or hinterland Ottoman communities (TIMI and DB), and the Ottoman sample from Budapest (JNT). As highlighted in both the PCoA plots and the DFA results, considerably more JNT females show strong biological affinities with the Anatolian series, not only separating them from the JNT males, but also from all other male and female Ottoman samples. This is not the case with the other two Ottoman localities, especially in Timișoara where more female individuals align with the comparative European populations. This trend is not matched in the males from the Budapest sample (JNT) however, who show a closer relationship overall with the European comparative series. Nevertheless, visualization of the overall affinity patterns suggests that Ottoman communities are biologically distinctive from the three comparative groups, indicating either possible admixture or the inclusion of biological variation not captured in the comparative populations considered in this study.

The results of the discriminant functions analyses, however, indicate that the vast majority of male and female Ottomans could be classified as being either European or Anatolian with typicality probabilities of  $p > 0.05$ . In the case of males, all but four of those classified as “other” also had posterior probabilities of 0.9 or higher, meaning that even amongst the males not deemed to be “typical” of the European or Anatolian reference series, the majority could be classified as Anatolian or European with relative certainty. In the case of the females, all but two specimens from Timișoara were assigned to either the European or Anatolian groups with high typicality probabilities. These DFA results help explain the apparent differences in craniometric affinity between Ottomans and the comparative populations found in the principal coordinates analyses, showing that Ottoman communities are not so much distinct biological populations but rather they appear to comprise a mix of peoples from different source populations, some of whom classify as being either European or Anatolian. If the Ottomans were distinct biological populations compared with the European or Anatolian reference series, then we should not expect such high typicality probabilities, nor such strong classification results overall. Therefore, taken together, the results suggest that the Ottoman communities sampled here each constituted groups of people from diverse biological backgrounds.

It is worth noting that males were, in general, much more definitively classified as being either European or Anatolian than females, with 32 out of 40 male Ottomans classified as either European or Anatolian with 100% posterior probability. However, it must be pointed out that this was due to the overall greater differences between the European and Anatolian reference samples, as males were less likely than females to be “typical” of either the European or Anatolian reference samples (Figure 5). Conversely, only 18 out of 42 female Ottomans were classified with 100% posterior probability, while all but two female specimens from Timișoara had high typicality probability scores. These differences between male and female classification rates must be viewed in the context of the average craniometric differences between the two reference samples used here. As shown in Figure 5, female Europeans and Anatolians were overall more similar, with DF score ranges that were contiguous (but not overlapping). In contrast,

male European and Anatolian DF scores were highly differentiated, making it easier to ascertain if male Ottomans were truly typical of one reference group or not. In any case, the presence of Ottoman specimens in both the male and female samples that could not be assigned to either reference category suggest the presence of admixture between peoples of European and Anatolian descent or, alternatively, a third or additional, external source of biological affinity not represented by the comparative samples analyzed here.

Conversion of Europeans to Islam was known to occur all over Southeast Europe, with more southern regions Ottomanized earliest (Minkov, 2004). Given that the European comparative series employed here did not include individuals from all parts of Southeast Europe, it is possible that the individuals classified as "other" originated from lands such as Bosnia, Greece, Bulgaria, or Albania. Additionally, individuals classified as 'other' may be migrants from non-European areas other than the Ottoman capital region of Anatolia, as the empire also encompassed parts of northern Africa and western Asia. As our comparative populations do not represent the full extent of biological ancestry likely involved in the conversion and migration processes that populated Ottoman Europe, it is unsurprising that some individuals did not classify completely into the two predefined comparative series. In fact, extensive admixture between peoples of European and Anatolian descent (as may be the case with some individuals classified as "other") is, in many ways, to be expected in these Ottoman communities given a combination of immigration and local conversion practices. The fact that the majority of Ottoman individuals (both male and female) were successfully classified as being typical of either European or Anatolian cranial affinity was rather unexpected.

The increased biological distance between males and females found in each of the three Ottoman groups could indicate that different social processes impacted males and females separately. With immigration from other regions of the empire and conversion of Europeans to Islam the two main processes thought to influence the biological makeup of European Ottoman communities, our findings of greater distances between males and females from the same community may indicate that some of the social processes or policies influencing migration and conversion impacted the sexes in dissimilar ways. Some historic records support the idea that males and females may have been diversely impacted. For example, in some areas, females used conversion as a means of securing divorce from Christian husbands (Baer, 2004). Migration too could be sex-specific, as the practice of *devşirme*, the levying of child tributes from European populations to be raised as Ottomans and relocated to serve the administration, targeted young males (Ágoston, 2009). Complementing these historic accounts, our results imply that Ottoman communities may have been comprised of males and females divergent from each other in terms of their ancestral backgrounds; how they came to be members of their respective Ottoman community might include individually distinctive histories.

The results of this research need to be considered in the context of the larger debate regarding the Ottoman Empire's impact on the European lands it historically occupied. Different written records discuss the roles of both migrations from Anatolia and local conversion

practices in creating the Ottoman populations settled throughout Southeast Europe. Despite historic evidence of both of these influences on the demography of European Ottomans, these communities are still often discussed as uniform groups of Muslim "Turks." The terms "Ottoman" and "Turk" have been used interchangeably by European intellectuals throughout history (Çirakman, 2002), a nomenclature that overemphasizes and oversimplifies the potential immigration waves from Anatolian and fails to indicate the potential biological diversity of these groups. Similarly, the role of conversion in explaining the biological backgrounds of European Muslim communities descending from the Ottomans has also been overemphasized (Zhelyazkova, 2002). While many modern scholars agree that the true composition of the Ottomans in Southeast Europe is not adequately understood (Dávid and Fodor, 2002; Gara, 2005; Kirmizialtin, 2007; Zhelyazkova, 2002), there has been little research conducted to directly assess the biological affinity of Southeast European Ottomans and how it compares to cultural and ethnic definitions ascribed both externally and internally on the Ottomans in Europe. The nature and impact of the Ottoman past in Europe, predominantly studied from a historical disciplinary point-of-view, can be better understood with the addition of anthropological research to help highlight an important period in European history.

Today, the designations of "Ottoman," "Muslim," or "Turk" separate these individuals from other communities in Southeast Europe. The fact that the modern descendants of some of these historic Ottoman communities are still Muslim keeps these divides rigid, with Europe frequently propagated as synonymous with Christianity and territorially defined in opposition to Islam (Jones and Graves-Brown, 2004). Misrepresentations of history that attribute the immigration of individuals from Anatolia ("Turks") or the mass conversion of Europeans to Islam as a solitary process defining the backgrounds of the Ottoman communities that settled in Europe in the 16th and 17th centuries have impacted the modern descendants of these communities, at times in very adverse ways. As these results show, however, not a single one of the Ottoman groups aligns closely as either Europeans or Anatolians, and when analyzed at the level of the individual, it is clear that Ottoman samples are composed of diverse people, many of whom could be classified as being either Anatolian or European with a large degree of accuracy. These results lend support to the conclusion that neither the conversion of Europeans to Islam nor the immigration of people from Anatolia can be singled out as the sole process creating Ottoman groups and that historic interpretations that overemphasize one process over the other are at odds with the biological data. While only a small part of the larger European region that shared this Ottoman history has been examined so far, it is clear that bioarchaeological evidence can illuminate the complex history of the Ottoman past.

## 5 | CONCLUSIONS

On the basis of assessments of craniometric affinity patterns, our results show that European Ottoman groups were distinct from reference populations drawn from Europe and Anatolia. Moreover, samples

from more geopolitically central locations within Ottoman Europe differed in their overall cranial affinity patterns compared with smaller, hinterland communities. In addition, differences between male and female Ottomans were much greater than the variation between sexes in reference populations drawn from Europe and Anatolia, indicating potential differences in the biological affinity patterns of Ottoman males and females. Classification analyses showed that all three Ottoman communities were composed of individuals that could be accurately classified as being either European or Anatolian in the majority of cases. However, some individuals could not be confidently assigned back to reference populations, suggesting the presence of admixed individuals or other sources of biological affinity not considered here. Taken together, our results suggest that both migration from other regions of the Ottoman Empire and conversion of Europeans were important processes in the creation of Ottoman biological affinity patterns.

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