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RESEARCH ARTICLE

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Biological diversity in an Islamic archaeological population: A radiogenic strontium isotope and craniometric analysis of affinity in Ottoman Romania

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Abstract

Objectives: Written accounts, as well as a previous craniometric study, indicate that migrations of non-Europeans and conversions of Europeans to Islam define Ottoman communities in Early Modern Europe. What is less clear are the roles of migration and admixture in generating intra-communal variation. This study combines craniometric with strontium isotope data to compare the cranial affinities of locally born and immigrant individuals. We predict that locally born individuals are more likely than non-locals to show evidence of admixture.

Materials and Methods: Radiogenic strontium isotope data for 21 Ottomans were compared against archaeological faunal values. Sixteen individuals with intact crania were also measured and compared against two comparative source populations from Anatolia and Europe. Discriminant function analysis assigned unclassified Ottoans to either comparative group based on typicality probabilities, with potential admixture established via intermediate morphology between the two source populations.

Results: Strontium isotope values revealed relatively high proportions of non-locals, consistent with high mobility documented historically. The sexes differed, with more males classifying as "typically Anatolian" than females. Locals and non-locals also had different cranial affinity patterns, with most classifying either as "typically Anatolian" or "typically European." Contrary to expectation, none of the locals were identified as intermediate, suggesting admixture rates were relatively low.

Conclusions: Consistent with historical records, the results revealed high levels of extra-regional migration, with most individuals identifiable as either typically Anatolian or European. Moreover, locals and non-locals differed craniometrically, with no signs of admixture between Anatolian migrants and European converts in locals. This suggests intra-communal divisions were maintained.

KEYWORDS

admixture, bioarchaeology, biological distance, geobiochemistry, Islam

1 | INTRODUCTION

History's great empires had a significant influence on the people and places they interacted with. Political expansions were responsible for the geographic dispersal of diverse people, as well as the spread of cultural elements such as religious systems. With the expansion of church and state often occurring simultaneously (Carey, 2011; Chidester, 2013; Comaroff & Comaroff, 1986; Kennedy, 2007), increased religious diversity and interactions between heterogeneous populations were typical outcomes of political conquests. In these contexts, divisions between different religious communities are often the focus of study, with differences *within* religious communities less commonly analyzed. This research explores internal differences during one specific historical expansion, the spread of the Ottoman Empire into Southeast Europe. The Ottoman Empire, a political entity centered in Anatolia, was arguably the most influential Islamic political entity in history. At their greatest extent, the Ottomans controlled most of the Middle East, northern Africa, as well as Southeast Europe (Woodhead, 2012, p. 1), joining together a vast array of people into one empire. Starting in the 1300s, this political power expanded north from the Anatolian peninsula into Southeast Europe. The Ottoman control of European lands brought a new religion, culture, and political administration into Europe. Consequently, this historical context allows for exploration of the outcomes of religious diversity and the interaction of heterogeneous populations under this political and religious power.

History records a number of political and social processes that may have contributed different people to the Ottoman populations settled in the newly conquered regions of Southeast Europe. Military activities and the need to establish political and economic infrastructure required the presence of Ottoman officials, administrators, and soldiers. These militaristic and political communities were staffed by individuals of varying positions, with different titles separating Muslim-born soldiers of Turkish descent (*sipāhīs*) and elite officials, typically converts from European populations (*kullar*) (Parry, 1990). This *kullar* class of janissaries, many of whom were men from the *devshirme* child tribute system responsible for converting thousands of European boys (Ágoston, 2009), were given power and privilege in the provincial and central administration (Parry, 1990). Historical documents detail the impact of migration and conversion trends among females as well. While many forced conversions were recorded (Minkov, 2004), females converted voluntarily in some contexts, for example, in pursuit of a divorce from a Christian husband (Baer, 2004).

A recently published craniometric distance analysis indicated that male and female Ottomans differed in terms of their patterns of craniometric affinity, when compared against comparative European and Anatolian groups (Allen & von Cramon-Taubadel, 2017). In that study, it was possible to classify many individuals as either European or Anatolian with a high degree of certainty (Allen & von Cramon-Taubadel, 2017). However, some individuals were not typical of either comparative population in terms of their craniometric affinities and may represent additional source populations or admixture among European and Anatolian migrants to the region. Moreover, the results suggested that significant intraregional as well as interregional variability existed among different Ottoman communities in Southeast Europe, consistent with the historically documented set of social and political processes associated with migration and conversion that occurred throughout the Ottoman period in Europe (Baer, 2004; Bulliet, 1979; Graf, 2017; Kirmizialtin, 2007; Pálffy, 2001; Zhelyazkova, 2002). What is unclear, however, is the extent to which Ottoman communities retained internal population structure resulting from diverse migrations. Moreover, given that there was continuous migration of individuals into Ottoman settlements, it is important to distinguish between the affinities of those individuals who were born and raised in a settlement from new migrants from outside the immediate region. This allows us to consider the dynamics of community formation and, eventually, the formation of an ethnic identity during an influential historical period. As such, the combination of isotope data to establish location of childhood and adult craniometrics to establish population affinity patterns represents a powerful means of assessing the relative roles of migration in creating a singular yet complex religious community based on common religious and political affiliation.

The aim of this study is to investigate internal population diversity within a single Islamic Ottoman garrison community (Timişoara) from western Romania (Figure 1) using two bioarchaeological lines of evidence: strontium isotope data to distinguish between "local" and "non-local" individuals, and craniometric data to assess their biological affinities relative to comparative populations from Anatolia and central/southeastern Europe. Timişoara (or "Temeşvar") was an important center of defense located on a northeastern border of the Ottoman European lands. Formerly part of the Hungarian kingdom, the Ottoman conquest of Timişoara converted the town into an important border garrison. Timişoara was an integral part of the northern defensive line of the Ottoman Empire's territory in Europe during the Early Modern Period (Hegyi, 2000), as well as a production center on the periphery of Ottoman-controlled land (Imber, 2002). During the establishment of the garrison in the mid-1500s, the ruling Islamic Ottoman community settled inside the walled town, with the indigenous population relocated to external suburbs (Draşovean et al., 2007). For a century and a half, the fortified town of Timişoara was governed by Islamic rule, and frequent migrations of soldiers, administrators, and other Ottomans contributed to its population (Ágoston, 2002). Migration of Ottomans from the capital region in Anatolia, as well other parts of the Ottoman-controlled territories, brought biologically diverse people into Europe, specifically to Ottoman garrisons like Timişoara (Dávid, 1999; Kasaba, 2012). Likewise, as noted previously, documented conversion practices transformed large numbers of European individuals into members of the Islamic Ottoman populace (Kirmizialtin, 2007; Minkov, 2004). Given that the cemetery sampled here represents ~150 years of burial history (i.e., six human generations), it is possible that we are sampling both first-generation migrants as well as the offspring of migrants from earlier periods of the town's Ottoman history. In particular, individuals identified as having a "local" strontium isotope signature are more likely to represent second- and subsequent-generation offspring. Therefore, we might

FIGURE 1 Map of Timişoara, Romania, with locations of comparative samples (E = European and A = Anatolian)

expect these individuals to display craniometric affinities consistent with admixture among, for example, Ottomans of European descent who converted to Islam and immigrated to Timişoara following conversion, and Muslim migrants from Anatolia or elsewhere in the Empire. We hypothesize that individuals with a "local" isotope signature will differ craniometrically from "non-locals" and that locally born individuals are more likely to display evidence of admixture between European converts and Anatolian migrants.

2 | MATERIALS AND METHODS

Starting in 2006, sections of the Timişoara Ottoman cemetery were excavated from the town center. Archaeologists with Muzeul Naţional al Banatului, Timişoara (the National Museum of Banat, Timişoara) excavated ~160 human skeletal remains dating to the 16th and 17th centuries (Draşovean et al., 2007; Draşovean, Suciu, & Diaconescu, 2016). The burials were associated with a wall remnant from one of the town's mosques and were oriented with the head to the west and the feet to the east. They were covered predominantly with wooden planks, and despite a soil type excellent for preservation, no clothing remnants and few grave accessories were found (Draşovean et al., 2007). These conditions are consistent with typical Islamic burial practices (Petersen, 2013). The human remains from this site represent a portion of the Islamic population who lived inside the walled garrison at Timişoara.

This study used two bioarchaeological methods to investigate population dynamics and group affinity: radiogenic strontium isotope analysis and craniometric analysis. Analyses of strontium isotope ratios extracted from human skeletal material are an effective means of exploring questions of human migration and identity (Bennike, Dobat, Frei, Lynnerup, & Price, 2011; Ezzo & Price, 2002; Giblin, Knudson, Bereczki, Pálfi, & Pap, 2013; Knudson, O'Donnabhain, Carver, Cleland, & Price, 2012; Torres-Rouff, Knudson, Pestle, & Stovel, 2015). Likewise, quantitative craniometric shape data repeatedly have 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; He et al., 2019; Herrera, Hanihara, & Godde, 2014; Hubbe, Harvati, & Neves, 2011; Pinhasi & von Cramon-Taubadel, 2009; Strauss & Hubbe, 2010; von Cramon-Taubadel, Stock, & Pinhasi, 2013). These two methods were combined in this study to assess the differences in craniometric affinity for locally versus non-locally born individuals from the Ottoman garrison at Timişoara.

2.1 | Samples for radiogenic strontium isotope analysis

Radiogenic strontium isotope analysis was conducted on a subset of the Ottoman cemetery. Enamel samples from 21 individuals buried in Timişoara were analyzed. The enamel samples were taken predominantly from adults (n = 19) comprising 11 males and 8 females.

Permanent teeth from two older juveniles were also analyzed. Sex was not estimated for the two juveniles, a standard practice (Scheuer & Black, 2000). The sampled teeth include premolars (n = 18) and molars (n = 3). Craniometric data were available for only 16 of the 21 individuals due to their completeness and adult status, so isotope and craniometric data were combined for these 16 individuals only.

While regional baselines of $^{87}Sr/^{86}Sr$ values from rock, water, archaeological human samples, and archaeological faunal samples have been published for the greater Hungarian Plain region adjacent to Timişoara (Giblin et al., 2013; Palmer & Edmond, 1989; Seghedi et al., 2004), the local baseline specific for the town had to be established. Contemporaneous archaeological fauna from stratigraphic layers associated with the town's Ottoman period, as well as earlier deposits from Timişoara's medieval period were analyzed. Enamel samples were utilized due to enamel's known resilience against diagenetic change (Bentley, 2006; Budd, Montgomery, Barreiro, & Thomas, 2000; Kohn, Schoeninger, & Barker, 1999; Lee-Thorp & Sponheimer, 2003). The faunal dental samples were drawn from three species: domestic pig (*Sus domesticus*), domestic dog (*Canis familiaris*), and sheep (*Ovis aries*), all species that have been successfully utilized in other similar analyses (Bennike et al., 2011; Bentley, Price, & Stephan, 2004; Budd, Millard, & Chenery, 2004; Knudson & Price, 2007). Mandibular enamel samples from 15 specimens (eight sheep, two domestic dogs, and five domestic pigs) established the local baseline values of $^{87}Sr/^{86}Sr$.

2.2 | Methods: Radiogenic strontium isotope study

The strontium isotope analysis was conducted at the Geochronology and Isotope Geochemistry Laboratory at the University of North Carolina at Chapel Hill. The surface of each tooth sample was cleaned with a Dremel tool sonicated between each use. A small sample of enamel was extracted manually, ground in a sterilized mortar and pestle, measured out to equal roughly 5 mg, dissolved in 550 μl of 3.5 M HNO_3, and centrifuged to ensure full dissolution and separation of any non-enamel solid particles. Strontium ion-exchange columns roughly 35 μl in diameter were utilized to isolate the strontium. EiChrom SrSpec resin, developed to isolate Sr from other elements in the matrix, was loaded into Teflon columns. The resin was cleaned with 18.2 MΩ·cm water from a DirectQ system followed by 3.5 M nitric acid (HNO_3). The dissolved enamel samples were loaded into the columns and rinsed repeatedly with rounds of nitric acid to pass elements other than strontium through the columns and leave the strontium adhered to the resin. The columns containing the resin and strontium were placed over acid-fluxed cleaned beakers, the strontium was eluted with water, and a single drop of 0.1 M phosphoric acid (H_3PO_4) was added. The beaker with the strontium and phosphoric acid combination was dried on a hotplate at 100°C. This column procedure is based on the development of this strontium-selective resin by chemists at the US Department of Energy funded Argonne National Laboratory (Horwitz, Chiarizia, & Dietz, 1992).

The strontium isotope analyses were performed on a VG Sector 54 thermal ionization mass spectrometer. The dried strontium and phosphoric acid were mixed with 1 μl of 2 M HCl and 1 μl of TaF_5 and dried on a pure rhenium filament. Sample analyses consisted of a three sequence multi-dynamic approach, with ~120 ratios measured. The mean 87Sr/86Sr value for the strontium standard, NBS-987, was 0.710250±0.000015 (2 sigma, n=25) during the timeframe of the analyses of the samples presented here. Internal error for each sample was lower than the reproducibility of the standard; thus, the 2σ uncertainty for $^{87}Sr/^{86}Sr$ for each unknown is ±0.000015.

2.3 | Samples for craniometric analysis

Alongside the strontium isotope analysis, a craniometric analysis comparing a sample of individuals from the Ottoman cemetery in Timişoara to comparative collections was conducted. While a previous craniometric study utilizing these comparative samples included 26 adult individuals from Timişoara (Allen & von Cramon-Taubadel, 2017), this study focused on the 16 crania for which strontium isotope data were also obtained. In general, this archaeological collection was highly fragmentary, so individuals were selected based on cranial completeness to maximize number of measurements that could be obtained. In addition, three comparative collections were sampled; a medieval European group from Hungary (Zalavár), an Early Modern Period European group from Austria (Berg), and a mixed-context Anatolian skeletal series (Table 1; Figure 1). The three comparative collections were selected to represent likely source populations known, from historical records, to have contributed to the Ottoman garrisons. In this study, the European samples were used to represent cranial morphology we might expect in European converts, while the Anatolian comparative group represented cranial morphology of immigrant Muslims from the Ottoman capital region.

The data for the two comparative European collections were taken from Howells' (1996) published craniometric database (Zalavár and the Berg). Individuals from these two collections were combined to create a European comparative sample from the same general geographic area. The use of a sample of central Europeans models the craniometric affinities that might characterize a diverse cemetery population comprised of European converts to Islam. Converts were originally members of a variety of Southeast European communities (Ágoston, 2009), so a combination of two craniometric populations from the area better represents this diversity. Indeed, this combined sample proved successful in distinguishing European cranial morphology from Anatolian morphology in a previous study (Allen & von Cramon-Taubadel, 2017). A sample of 40 individuals from Zalavár and 30 individuals from Berg were combined to create the European comparative series. In addition to the two European groups, an Anatolian comparative series was collated based on Turkish and Syrian collections of human crania housed in the Anthropology Department of the American Museum of Natural History (AMNH) in order to provide a representation of craniometric variability from the capital region of the Ottoman Empire. Individuals from Aintab (today Gaziantep), Antalya, and Adalia in Turkey, as well as Aleppo (Syria) were sampled. This comparative sample of 31 individuals from Anatolia was also used in a previous analysis of Ottoman craniometric affinity, and was shown to represent a coherent and morphologically distinct cranial affinity sample from the European samples from Berg and Zalavár (Allen & von Cramon-Taubadel, 2017).

2.4 | Methods: Craniometric study

For both the Ottoman and Anatolian skeletal series, a sample of near-complete adult crania were selected, and age and sex were assessed using standard osteological techniques (see Allen & von Cramon-Taubadel, 2017 for a description of the methodology). Thirty-two craniometric caliper measurements were collected from each cranium (Table 2), with measurement protocols and definitions following Howells' (1973). The metric data for the Ottoman (Timişoara) and Anatolian series were collected by KG Allen, while data for individuals from the Zalávar and Berg collections were collated from Howells' publicly available database (1973, 1996). Prior to data collection, an inter-observer analysis was performed. Eight of the Berg specimens measured by Howells and curated at the AMNH were remeasured by KGA to ensure compatibility of measurements between Howells' data and those collected for the purposes of this study (Allen & von Cramon-Taubadel, 2017).

Following the collection of craniometric measurements, missing data were estimated for 5.7% of the total measurements using multiple linear regression interpolation by sample. 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). This treatment ensured overall size for each cranium was not over-represented in analysis of variance, thereby allowing the craniometric data to highlight shape variation among individuals (Jungers et al., 1995).

A discriminant function analysis (DFA) was performed to ascertain whether the two comparative groups ("Anatolian" and "European" [comprised of the Berg and Zalavár samples]) were sufficiently morphologically distinct to act as useful reference populations against which to assess population affinities of the Timişoaran specimens.

TABLE 1 Four craniometric series utilized in this research

Skeletal series	Time period	Museum	Location of collection	Males	Females
Timişoara	Ottoman (16th and 17th C)	Muzeul Naţional al Banatului, Timişoara (*National Museum of Banat, Timişoara*)	Timişoara, Romania	*N* = 8	*N* = 8
Zalavár	Medieval (9th–11th C)	Magyar Természettudományi Múzeum (*Hungarian Natural History Museum*)	Budapest, Hungary	*N* = 20	*N* = 20
Berg	Early Modern (17th–19th C)	American Museum of Natural History	New York City, United States	*N* = 15	*N* = 15
Anatolian	Various	American Museum of Natural History	New York City, United States	*N* = 19	*N* = 12

TABLE 2 Howells' measurements collected

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

High biological distance between sexes in the Timişoara garrison highlighted in a previous study (Allen & von Cramon-Taubadel, 2017) indicates that conversion and migration trends likely impacted the sexes in different ways. Therefore, males and females were analyzed separately. Typicality probabilities based on Mahalanobis' distances to the comparative groups' centroids were used to assess the probability that each individual was "typical" of either the European or Anatolian groups, and were also subsequently used to assess the likely classification of the Ottoman specimens from Timişoara. Unlike posterior probabilities, which force individuals to be classified into one of the given reference series, typicality probabilities allow for the possibility that an unclassified individual is not typical of *any* of the comparative groups included in the analysis (Kovarovic, Aiello, Cardini, & Lockwood, 2011). While our choices of comparative groups are supported by historical accounts of likely source populations for Ottoman Romania (i.e., central and eastern Europeans and Anatolians), it is possible that other source populations, not assessed here, contributed to the biological make-up of the Timişoaran sample. Similarly, admixture among individuals of central European and Anatolian descent could result in an intermediate morphology (Algee-Hewitt, 2016; Martínez-Abadías et al., 2006), which may be atypical of one or the other parental population. Consequently, typicality probabilities provide a more realistic measure of group affinity and allowed for the possibility that Ottoman crania were insufficiently represented by the comparative samples employed here. In discriminant function analyses that use typicality probabilities, classifications of $p < .05$ are used to reject an individual's membership to a comparative group. Discriminant function analyses were performed in SPSS v. 25.

In the case of reference sample males, 100% of specimens correctly classified back to the reference group ("Anatolian" or "European") with high typicality probabilities ($p > .05$) (Table S1). In the case of females, 100% of Anatolian specimens classified as "Anatolian," while 33/35 European females classified as being typically "European" ($p > .05$) (Table S2). Of the two misclassified European females, one was equally typical of both reference series (typicality probabilities $p = .06$ for both Anatolian and European), while the other was found to be more typical of the Anatolian series ($p = .148$) and atypical of the European series ($p = .024$). The most likely reason for the misclassification of these two European females was the overall lesser degree of craniometric differentiation between European and Anatolian females in terms of their discriminant function scores (see Table S2). Hence, females from the reference samples are more likely than males to display an intermediate cranial morphology. Nevertheless, despite some shared similarities between European and Anatolian females, the overall level of correct classification to known groups for the European and Anatolian comparative samples was very high (>94%), indicating that it is possible to distinguish between these two likely source populations with a high degree of certainty.

Given this, for the unclassified Ottoman crania from Timişoara, four classifications were possible:

1. Typical European: high typicality probability of belonging to the European comparative sample ($p > .05$) and a low typicality probability of belonging to the Anatolian comparative sample ($p < .05$).
2. Typical Anatolian: high typicality probability of belonging to Anatolian comparative sample ($p > .05$) and a low typicality probability of belonging to the European comparative sample ($p < .05$).
3. Intermediate: high typicality probability of belonging to both the European and Anatolian comparative sample ($p > .05$).
4. Atypical: low typicality probability of belonging to either the European or the Anatolian comparative sample ($p < .05$).

Using the discriminant function scores generated for male and female reference samples, each unclassified Ottoman cranial specimen from Timişoara was assigned to the European and Anatolian comparative groups, with a step-wise method being employed to retrieve the typicality probability of each Ottoman individual being classified as either European or Anatolian. Typicality probabilities were employed to assess each Ottoman individual against the four classificatory possibilities listed above, alongside the consideration of whether their strontium isotope signature labeled them as "local" or "non-local." For those individuals who were not typical of either of the two comparative groups (i.e., those who fall under Categories 3 and 4), various explanations were considered. Individuals who are atypical of both groups might have come from a source population different from those represented by our comparative samples. The Ottoman Empire was a vast entity, which at times included parts of northern Africa and the Caucuses (Woodhead, 2012). Consequently, it was anticipated that some individuals may fail to classify in categories defined by our comparative samples. For any individuals falling in an intermediate position (Group 3), it is plausible that these might represent admixture between the Anatolian Ottomans and European converts, as previous research has shown that admixture generates intermediate cranial shape morphology among human groups (Martínez-Abadías et al., 2006). Deciphering the morphological outcome of admixture in a

TABLE 3 Faunal dental samples used in strontium isotope analysis (Sr data are relative to 0.710250 for NBS 987, $2\sigma = 0.000015$)

Lab ID	Temporal context	Sample type	$^{87}Sr/^{86}Sr$ value
A-1	Medieval	Sheep	0.710360
A-2	Medieval	Sheep	0.710227
A-3	Medieval	Sheep	0.709996
A-4	Ottoman	Sheep	0.710066
A-5	Medieval	Domestic dog	0.710158
A-6	Medieval	Domestic dog	0.711044
A-7	Medieval	Domestic pig	0.711254
A-8	Medieval	Domestic pig	0.711505
A-9	Medieval	Domestic pig	0.711086
A-10	Ottoman	Domestic pig	0.709782
A-11	Ottoman	Domestic pig	0.710760
A-12	Ottoman	Sheep	0.711043
A-13	Ottoman	Sheep	0.711274
A-14	Ottoman	Sheep	0.709953
A-15	Ottoman	Sheep	0.710736

complex skeletal element such as the human cranium is difficult as the cranium is influenced by integration, environmental factors, and plasticity, among other processes (Martínez-Abadías et al., 2006). Nevertheless, as Ottoman Muslims of European descent (converts) and those of Anatolian descent were cohabiting for many generations inside Ottoman military garrisons, admixture was likely to occur. We can postulate that those classified as "intermediate" may represent this outcome. Moreover, we expect that local-born individuals are more likely to represent intermediary morphology than non-locals, given they represent second- or subsequent generation Ottomans of a shared politico-religious identity, regardless of their original population affinities.

3 | RESULTS

3.1 | Results of strontium isotope analysis

Table 3 displays the $^{87}Sr/^{86}Sr$ values for the 15 archaeological animal samples utilized as a local baseline, with a minimum value of $^{87}Sr/^{86}Sr = 0.709782$ and a maximum value of $^{87}Sr/^{86}Sr = 0.711505$. These faunal values reflect the local, biologically available strontium accessible for uptake by those who consumed strontium via local food and water during enamel development. Table 4 displays the $^{87}Sr/^{86}Sr$ values for the 21 human enamel samples tested from the Timişoara Ottoman cemetery, with the 16 samples for whom craniometric data were also available in bold. The minimum value among the human dental enamel samples was $^{87}Sr/^{86}Sr = 0.707942$ and the maximum was $^{87}Sr/^{86}Sr = 0.710749$ (Figure 2). Eleven human samples fell outside the local range, while 10 individuals displayed strontium signatures consistent with the "local" signal. Of the 16 individuals for whom craniometric data were also assessed, 10 fell outside the local baseline range ("non-local"), while six samples displayed strontium values compatible with the expected range for people who consumed food raised in and around the Ottoman town during childhood amelogenesis ("locals"). It is important to note that a "non-local" signature does not necessarily designate immigrants from outside of Europe (from Anatolia or elsewhere). European converts from communities all over Southeast Europe could have "non-local" strontium signatures. Rather, the division between "non-locals" and "locals" was considered to indicate whether or not an individual arrived to the Timişoara garrison during their lifetime, or whether they were the child or descendant of individuals who relocated to the garrison during the 150 years in which Timişoara was used as an Ottoman outpost. Recent research analyzing intraindividual variability and laboratory precision of $^{87}Sr/^{86}Sr$ values was considered when inferring which individuals should be assigned as "local" or "non-local." Knudson, Stanish, Lozada Cerna, Faull, and Tantaleán (2016) found

TABLE 4 All human dental samples (n = 21), from the Ottoman site of Timişoara in Romania, used in the strontium isotope analysis (Sr data are relative to 0.710250 for NBS 987, 2σ = 0.000015)

Lab ID	Tooth	Sex	Age	$^{87}Sr/^{86}Sr$ value	Local/non-local
H-1	**LP^2**	**M**	**Adult**	**0.710304**	**Local**
H-2	**RP_1**	**F**	**Adult**	**0.709664**	**Non-local**
H-3	**RP^2**	**F**	**Adult**	**0.708874**	**Non-local**
H-4	LP_2	NA	Juvenile	0.710457	Local
H-5	**LP^1**	**F**	**Adult**	**0.710312**	**Local**
H-6	**RP_2**	**M**	**Adult**	**0.709038**	**Non-local**
H-7	**RP_2**	**M**	**Adult**	**0.708160**	**Non-local**
H-8	**RP^2**	**F**	**Adult**	**0.708790**	**Non-local**
H-9	**RP_2**	**F**	**Adult**	**0.710528**	**Local**
H-10	**RP_2**	**M**	**Adult**	**0.709648**	**Non-local**
H-11	LM_3	M	Adult	0.707942	Non-local
H-12	RM^3	M	Adult	0.710413	Local
H-13	LP^2	NA	Juvenile	0.710458	Local
H-14	RP_1	M	Adult	0.710651	Local
H-15	**LP^1**	**M**	**Adult**	**0.708796**	**Non-local**
H-16	**RM^3**	**F**	**Adult**	**0.710443**	**Local**
H-17	**LP_2**	**F**	**Adult**	**0.708876**	**Non-local**
H-18	**RP^1**	**F**	**Adult**	**0.710749**	**Local**
H-19	**LP^2**	**M**	**Adult**	**0.708848**	**Non-local**
H-20	**LP^2**	**M**	**Adult**	**0.708338**	**Non-local**
H-21	**RP_1**	**M**	**Adult**	**0.710676**	**Local**

Notes: Bold terms designate those individuals for whom craniometric data were also available.

that conclusions based on $^{87}Sr/^{86}Sr$ values at the fifth decimal point were not as reliable as differences detected at the fourth decimal point in interpretations of mobility and migration. When only the first four decimal points of the values obtained in our study were considered, the same proportion of "locals" to "non-locals" was upheld, supporting the designations provided in Table 4.

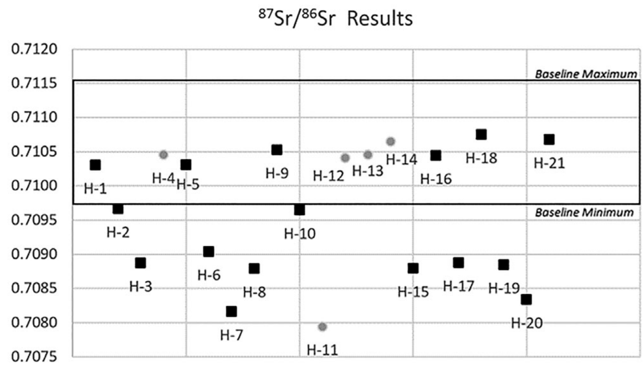

FIGURE 2 Plot of human strontium isotope values rounded to the first four decimal values. Black box designates baseline local range determined by archaeological faunal values. While this figure displays all of the 21 human strontium values obtained, the black squares designate the 16 individuals for which craniometric data were also available

3.2 | Results of DFA

As there were only two reference groups, a single discriminant function was extracted as a linear combination of the craniometric shape variables that best separated the European and Anatolian reference samples (see Tables S1 and S2). Table 5 shows the proportion of Ottoman individuals classified as either European or Anatolian according to a high typicality probability for their designated group ($p > .05$), and a low typicality for the alternative group ($p < .05$). Individuals with high or low typicality probabilities for both are listed as intermediate or atypical (respectively). For the Ottoman males, half the sample was classified as typically Anatolian, 38% as typically European, and one individual (12%) was classified as atypical of either group with an intermediate morphology based on their position along the discriminant function score (Figure 3). For females, 38% were classified as European, 25% as typically Anatolian, 25% as atypical for either group, and one individual (12%) was classified as intermediate and typical of both groups (Table 5, Figure 4). Hence, more males were classified as Anatolian than females, which mirrors findings from a previous study

TABLE 5 Discriminant function analysis results for males and females

	European	Anatolian	Intermediate	Atypical	Total sample
Ottoman males	3 (38%)	4 (50%)	1 (12%)	0 (0%)	8
Ottoman females	3 (38%)	2 (25%)	1 (12%)	2 (25%)	8

Notes: Number of individuals (percentage of sample) classified as either European or Anatolian with typicality probabilities of $p > .05$ for category membership (and $p < .05$ for the other group). The "Intermediate" category indicates individuals who were intermediate between both populations, while "Atypical" refers to individuals who were not typical of either the European or Anatolian comparative samples ($p < .05$).

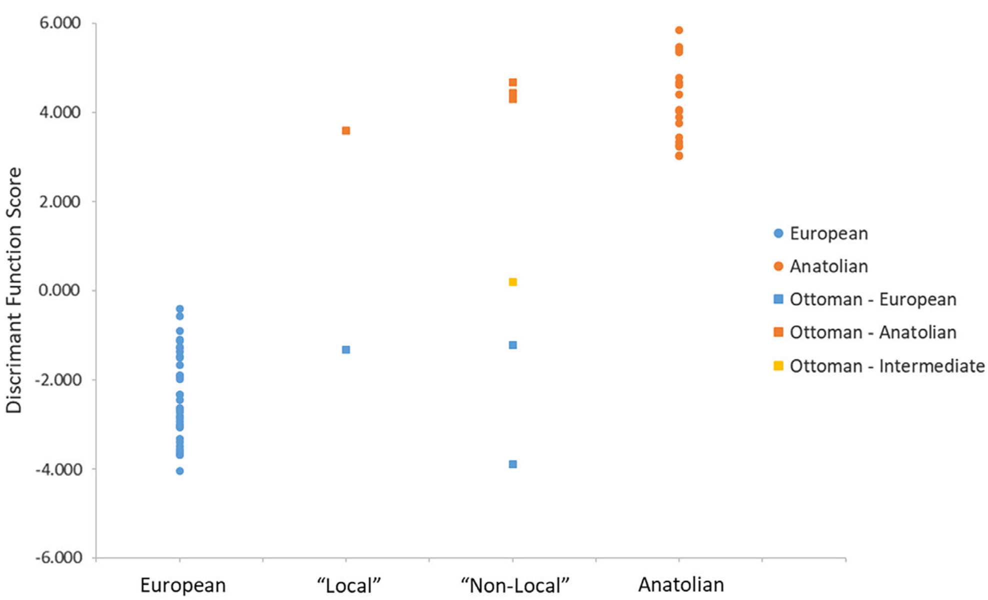

FIGURE 3 Discriminant function scores for male craniometric data from two comparative samples (European and Anatolian) and unclassified Ottoman crania from Timisoara, identified on the basis of strontium isotope data as being either "local" or "non-local" in origin. The intermediate individual had a low typicality probability ($p < .05$) of belonging to either reference sample but occupied an intermediate position between the European and Anatolian centroids

using a larger craniometric dataset from Timişoara (Allen & von Cramon-Taubadel, 2017).

3.3 | Results: Combination of isotope and craniometric affinity analyses

Table 6 shows the combined strontium isotope and discriminant function classification analyses for the 16 individuals common to both datasets. Typicality probabilities for each reference sample are provided in Table 6 and summaries of classifications according to the four possibilities listed above are provided in Table 7. There were more non-local individuals (n = 10) than local individuals (n = 6), overall (Table 7). In particular, there were substantially more non-local males (n = 6) than local males (n = 2) (Figure 3), consistent with historical accounts of the continual movement of migrants from outside the region to the town of Timişoara (Ágoston, 2002).

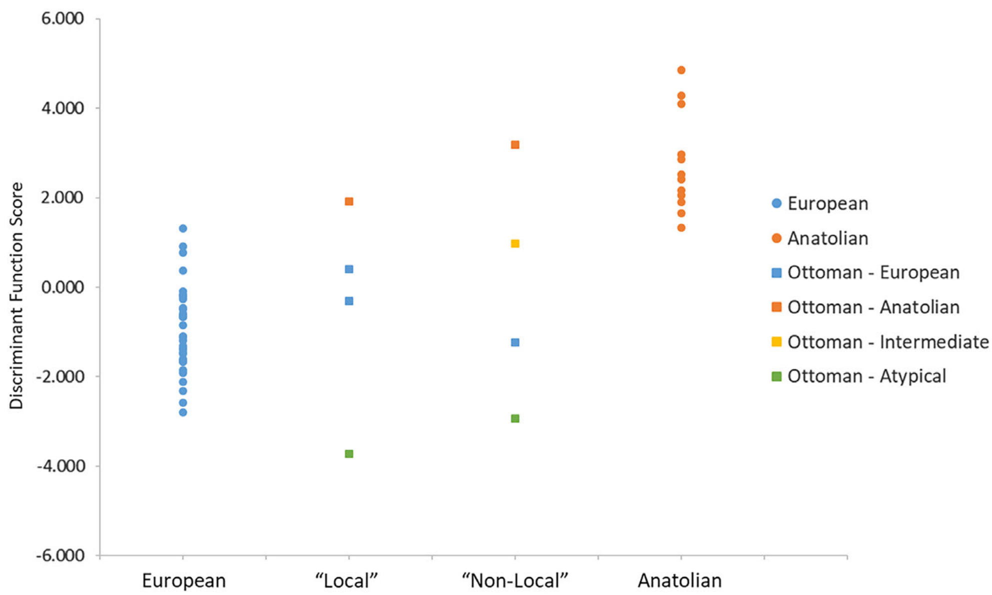

FIGURE 4 Discriminant function scores for female craniometric data from two comparative samples (European and Anatolian) and unclassified Ottoman crania from Timisoara, identified on the basis of strontium isotope data as being either "local" or "non-local" in origin. The intermediate individual had a high typicality probability ($p > .05$) of belonging to both reference samples, while the "atypical" individuals were not typical of either group ($p < .05$) and occupied the extreme "European" end of the discriminant function score

TABLE 6 Combination of the strontium isotope and craniometric discriminant function data for the 16 individuals common to both datasets

Lab ID	Local/non-local	$^{87}Sr/^{86}Sr$ value	Sex	Classification	Typicality probability[a] (European/Anatolian)
H-1	Local	0.7103	M	European	0.31/0.00
H-21	Local	0.7107	M	Anatolian	0.00/0.47
H-5	Local	0.7103	F	European	0.18/0.02
H-9	Local	0.7105	F	Anatolian	0.01/0.40
H-16	Local	0.7104	F	Atypical	0.01/0.00
H-18	Local	0.7107	F	European	0.53/0.00
H-6	Non-local	0.7090	M	Anatolian	0.00/0.99
H-7	Non-local	0.7082	M	Intermediate	0.01/0.00
H-10	Non-local	0.7096	M	Anatolian	0.00/0.71
H-15	Non-local	0.7088	M	European	0.12/0.00
H-19	Non-local	0.7088	M	Anatolian	0.00/0.91
H-20	Non-local	0.7083	M	European	0.26/0.00
H-2	Non-local	0.7097	F	Intermediate	0.05/0.08
H-3	Non-local	0.7089	F	Atypical	0.05/0.00
H-8	Non-local	0.7088	F	European	0.78/0.00
H-17	Non-local	0.7089	F	Anatolian	0.00/0.66

Notes: Typicality probabilities are shown for both the European and Anatolian groups. Intermediate individuals are those that display intermediate craniometric affinities for both groups (Figures 3 and 4), while atypical individuals were not typical of either comparative groups. See text for discussion of differences between the male and female typicality probability ranges.

[a]Values denoted as 0.00 indicate a typicality probability of $p < .0001$.

TABLE 7 Discriminant function analysis results for local and non-local individuals

	European	Anatolian	Intermediate	Atypical	Total sample
Ottoman non-locals	3 (30%)	4 (40%)	2 (20%)	1 (10%)	10
Ottoman locals	3 (50%)	2 (33%)	0 (0%)	1 (17%)	6

Notes: This sample size is smaller than the total number of individuals analyzed for strontium and presented in Table 4 due to the unavailability of craniometric data for five individuals. Number of individuals (percentage of sample) classified as either European or Anatolian with typicality probabilities of $p > .05$ for category membership (and $p < .05$ for the other group). The "Intermediate" category indicates individuals who were intermediate between both populations, while "Atypical" refers to individuals who were not typical of either the European or Anatolian comparative samples ($p < .05$).

In terms of cranial affinity, the two local males were evenly split, with one individual classified as "typically" European and the other as "typically" Anatolian (Figure 3), while local females were primarily classified as being typically European or atypical but on the extreme "European" end of the discriminant function score (Figure 4). In the case of both sexes, there were no local individuals classified as being intermediate between Anatolian and European cranial morphology. However, in both sexes, there was one non-local individual classified as having intermediate morphology (Tables 5 and 7), yet is worth noting that intermediate morphology was relatively rare, characterizing only 12.5% of the cranial sample tested.

In the case of females, it must be remembered that the difference along the discriminant function between the average position of the European and Anatolian reference samples was overall smaller (see Table S2), indicating that European and Anatolian females were more difficult to differentiate based on cranial shape than males (see also Allen & von Cramon-Taubadel, 2017). Hence, due to this sex-based bias, it was expected that more female Ottomans may fail to classify as being typical of the European or Anatolian reference samples. However, this was not the case as only one (non-local) female was classified as being intermediate in morphology. Contrary to the male data, more Ottoman females were classified as either typically European or on the extreme European end of the discriminant function (Figure 4) than typically Anatolian. One individual was classified as being typical of both the European and Anatolian samples and occupied an intermediate position along discriminant function 1. Also contrary to the male data, an equal number of females were identified as local and non-local. Finally, the local females could be clearly identified as either typically Anatolian, typically European, or atypical of either group but with an extreme morphology not shared by either comparative group.

4 | DISCUSSION

The Ottoman Empire, one of history's most influential Islamic states, expanded into Southeast Europe starting in the 15th century. Historical evidence indicates that migration significantly influenced demography (Pálffy, 2001; Zhelyazkova, 2002). Additionally, large-scale conversions of Europeans to Islam were also substantiated in written accounts (Baer, 2004; Bulliet, 1979; Graf, 2017; Kirmizialtin, 2007). The craniometric and radiogenic strontium isotope analysis we present here allow for an assessment of the relative contribution of migration and conversion in creating the biological population structure observed in an Ottoman cemetery in the garrison city of Timişoara in western Romania.

The strontium isotope analysis highlighted a diverse sample of individuals buried in the Islamic cemetery in Timişoara. Our results found a slightly higher proportion of non-local individuals (11 out of 21), particularly in the male sample (64% of males were non-local) (Table 4). This is consistent with historical accounts of high levels of mobility during the Ottoman period, particularly for a garrison city such as Timişoara located in a geographic area of strategic military and administrative importance (Ágoston, 2009b; Dávid, 1999; Hegyi, 2000; Imber, 2002). Throughout its 150-year use, historical accounts detail the movements of soldiers, administrators, and other Ottomans into the garrison (Ágoston, 2002; Dávid, 1999). These migrations and dispersals contextualize why more males were non-local than local in our sample. Individuals with local signatures were represented as well, with four male, four female, and both juvenile samples testing within the local range determined by the archaeological faunal sample. With historical accounts detailing the removal of the indigenous population from the city center (Draşovean et al., 2007), local in this study likely indicates a second or subsequent generation of immigrants to Timişoara, rather than membership to the community native to the area prior to Ottoman arrival. Consequently, our sample includes not only individuals who moved into Timişoara during their lifetimes, but also those born in the garrison. In terms of locality, this sample is diverse with both males and females represented in both local and non-local subgroups.

The results of the DFA illuminate population dynamics as well. The DFA found differences between males and females in terms of their classifications as typically European, typically Anatolian, intermediate, or atypical, with proportionately more males classified as typically Anatolian, and more females classified as European or on the extreme European end of the discriminant function score (Table 5, Figure 4). It is worth noting that the average differences between typical European and typical Anatolian cranial affinity was much larger for males than for females, making the possibility of finding intermediate morphology in females more likely. This was not the case, however, with only one female (and one male) displaying intermediate morphology. Moreover, only female Ottomans displayed morphology atypical of either reference sample, and both of these specimens were found to exhibit extreme versions of the European cranial morphology. This may indicate other European source populations not captured by the cranial variation of our comparative samples from Europe and Anatolia.

Our hypothesis was that locally born and non-local migrants would exhibit different cranial affinity signatures, with locals more likely than non-locals to display intermediate morphology as a consequence of admixture. Contrary to our expectations, there were only two individuals of intermediate morphology (one male and one female out of 16 crania). Neither of them had a local strontium signal, the potential outcome of admixture in Timişoara-born individuals of Anatolian and European descent. Instead, the synthesis of the craniometric and isotope data suggests that admixture rates were comparatively low in Ottoman Timişoara, at least for the cemetery sample analyzed here. All locally born individuals classified as either typically Anatolian, typically European, or exhibiting extreme "European" morphology outside the range of variation of the comparative samples (Figures 3 and 4). Hence, this small sample of locally born second- or subsequent-generation immigrants raised in Timişoara suggests that intra-communal divisions between peoples of European and Anatolian heritage may have been retained generationally, resulting in offspring that tended to resemble one or the other parental populations rather than a mix of the two.

Admixture results from the homogenizing effects of gene flow between populations that were previously reproductively isolated, as is often the outcome from mass migratory or colonization processes (Martínez-Abadías et al., 2006). Previous DNA studies have successfully reconstructed the biological impacts of global migrations, identifying historical admixture in genetic data (Hellenthal et al., 2014; McEvoy, Brady, Moore, & Bradley, 2006; Patterson et al., 2012; Zalloua et al., 2008). Likewise, morphological analyses have detected admixture in craniofacial forms, as phenotypic indicators of admixture are seen in the intermediary morphological forms between parent populations (Martínez-Abadías et al., 2006; Ross, Slice, Ubelaker, & Falsetti, 2004). The combination of craniometric and radiogenic strontium isotope data allowed us to investigate the outcome of cohabitation between biologically diverse people, brought together under a shared identity (Ottoman Muslims) defined by nonbiological factors (religion and political affiliation).

The Ottoman community in Timişoara was unified by shared religious and political membership. Consequently, it might be expected that biological divisions between Ottomans of Anatolian descent and converts originating from non-local European populations would begin to disintegrate following the first generation of arrivals to the garrison. The current study has a rather unique context in this regard, as most post-contact studies focus on the biological consequence of contact between the colonizing power and the indigenous community (rather than contact between different contingencies that composed the colonizing community itself). Regardless, admixture is well-documented in colonial contexts overall (Hellenthal et al., 2014), making it a reasonable assumption for our study. Our results do not follow this expectation, however, as the "locals" in our Ottoman sample classified as one of the two source populations or at the extreme European end of the craniometric affinity pattern. Hence, despite shared political and religious identity, the Ottomans in Timişoara appear to have retained substantial population substructure within the community.

Given the lack of evidence for admixture presented here, it is instructive to consider what restrictive barriers to gene flow among immigrant groups may have existed. Without physical and religious barriers within the Ottoman Muslim community, cultural, linguistic, political, or economic barriers restricting admixture should be considered instead. Differences between Ottomans of Anatolian descent versus those originating from European populations are supported by historical documentation. Records show that Europeans converted to Islam under a variety of circumstances, both forced and voluntary in nature (Ágoston, 2009; Baer, 2004; Börekçi, 2010; Graf, 2017; Kirmizialtin, 2007; Sobers-Khan, 2014). Many converts enjoyed benefits from conversion (Kirmizialtin, 2007; Minkov, 2004). However, written documents also detail consequences for those who chose or were forced to adopt Islam, with converts often labeled as "renegades" by Christian communities (Graf, 2014, 2017). As people who deserted their faith, renegades were described by Europeans as more untrustworthy compared to "trueborn Muslims" (Kármán, 2014; Nagy, 1672). Additionally, there are written accounts of converts who remained loyal to Christian states as spies (Graf, 2014). This could have garnered mistrust from their new religious communities, in addition to the mistrust from the European communities from whom they separated. Likewise, linguistic barriers should be considered. While some converts were educated in Islamic customs and the basics of the Turkish language (Ágoston, 2009), linguistic barriers between converts from different parts of Southeast Europe as well as with immigrants from Anatolia likely added intracommunity barriers to marriage. Documentation of converts switching back to their original religious communities (Graf, 2014), and borderland communities altering their ethnic and religious identities to negotiate changing political situations (Blumi, 2003) could evince motivation to retain biological divisions generationally. Finally, historical documentation indicates that some European converts enjoyed preferential treatment and elite positions over Muslims of Turkish descent (Parry, 1990). This may have created tension between European converts and Anatolian Muslims, reinforced political and social boundaries, and discouraged admixture within a single Ottoman community. It is clear that numerous social, political, and economic barriers could explain a lack of biological admixture.

In addition to exploring the possibility of admixture in a religious community likely composed of biologically diverse individuals, this archaeological context highlights other important aspects of human identity in colonial environments. For over 150 years, the city of Timişoara was inhabited by a new community and a distinct political power. When the Ottomans gained control of the region, a new community of Islamic inhabitants governed the city. A century and a half later, the Habsburg army would overthrow Islamic rule, burn the fortress city to the ground, and rebuild it into a Christian province once again. None of the Islamic community remained following the overthrow (Mitchell & Kicošev, 1997). While elsewhere in Southeast Europe the Ottoman history left permanent Islamic communities, the modern city of Timişoara has few reminders to its Islamic past. The Ottoman identity ceased to be present in this part of western Romania following the retreat of the Ottoman Empire in the 18th century. Still, this group highlights the dynamic nature of a unique colonial identity. The Islamic community at Timişoara would have been by-and-large reproductively isolated from the indigenous community due to religious doctrine, with little historical evidence that immediately local conversions were significant. While it is possible that some local families converted, this is not believed to have been the outcome for most of the indigenous population (Dávid, 1999). Likewise, we know that many conversion campaigns focused on populations further south (Ágoston, 2009) as more "preferred" communities to receive converts from. The biological heterogeneity of the Ottoman community therefore, was likely caused by migration from outside of Timişoara. The constant influx of new Ottomans from other regions of southeastern Europe, Anatolia, and the rest of the Ottoman world created a truly heterogeneous community. While sharing a politico-religious identity, diversity in ancestral background, connection to Islam, language, and cultural traditions from Ottomans originating from these diverse communities would have made for a truly complex identity group.

Postcolonial theories, a recently developed group of theoretical ideas, have been instrumental in reevaluating colonial archaeological contexts (e.g., Ferris, Harrison, & Wilcox, 2014; Horner, 2015; Naum, 2010; Pragnell, 2013; Rizvi, 2008; Van Oyen, 2013). Postcolonial theories encourage approaching colonial contexts as a complex, hybrid mix of original parts, rather than a simple narrative of two discrete cultures coming together (Gosden, 2001). The hybridization of culture under examination in postcolonial studies typically refers to an interplay between the colonizers and the colonized. In our work, however, a new identity emerges from the hybridization of diverse cultures constituting only one of these entities: the colonizers. This allows our study to contribute uniquely to larger conversations of identity in colonial contexts from the past.

The results suggest differences between "locals" and "non-locals" in terms of cranial affinity while highlighting low levels of admixture among locally born individuals, contrary to expectations. Caution must be exercised in the interpretation of these findings given the small sample size available, particularly for the combined strontium isotope and craniometric datasets. Nevertheless, small samples sizes are not unusual for an archaeological sample of this nature (Evans, Stoodley, & Chenery, 2006; Roberts et al., 2013; Turner et al., 2012), particularly when combining the need for well-preserved crania and in situ teeth for strontium isotope analysis. As such, we believe that the results presented here offer insight into the migration and population dynamics of a European Ottoman city. As one of few bioarchaeological research agendas focused on the Ottomans in Europe, we hope this study will spark new efforts to explore the Ottoman history in Europe, an often ignored time period in European archaeology (Baram & Carroll, 2002; Vorderstrasse, 2014). In the future, the addition of new comparative populations, as well as the application of this methodology to other Ottoman settlements around the former empire, will add to our understanding of community identity in this complex colonial context.

5 | CONCLUSION

At many times in history, Southeast Europe experienced cultural and political events that impacted the population history of the region. While research has analyzed the biological impacts of ancient migrations on this region (Battaglia et al., 2009; Bosch et al., 2006; Mirabal et al., 2010; Rootsi et al., 2007), as well as modern population demography and morphology (Malyarchuk et al., 2003; Ross, 2004), the population impacts stemming from the Ottoman period are less well-understood. The results of this craniometric and radiogenic strontium isotope analysis reveal differences between locally born individuals and migrants in terms of their cranial affinities, with relatively few individuals displaying evidence of admixture between Anatolian migrants and non-local European converts. Moreover, contrary to expectation, none of the locally born individuals showed evidence of admixture, which suggests that, at least in this small sample, intra-communal divisions between immigrants from Anatolia and converted Europeans may have been upheld. This sample shows a variety of population affinities in both individuals born in the garrison and those migrating in during their lifetimes. As the ruling power in the Islamic fortress, the Islamic community was in actuality a diverse hybrid, a coalition of individuals with varying ancestral backgrounds whose common politico-religious affiliations brought them together to create a complex identity group.

History's major religions have profoundly impacted the world. Despite shared faith, practices, and religious identity, members of a single religious group should not be considered a homogeneous community. Within major world religions such as Islam, considerable internal population differences can be found. Hence, in archaeological contexts with evidence of a shared religious identity, a deeper look at internal population structure can provide considerable insight into the community's social and biological composition.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

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