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Mediterranean Archaeology and Archaeometry
Vol. 20, No 2, (2020), pp. 35-44
Open Access. Online & Print.

DOI: 10.5281/zenodo.3752145

A PRELIMINARY STUDY ON THE ANCIENT MIGRATIONS IN TEPE SILVEH PIRANSHAHR, (NORTH-WESTERN IRAN) BASED ON STRONTIUM ISOTOPES OF SKELETONS

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Received: 27/01/2020
Accepted: 14/04/2020
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ABSTRACT

In this work, strontium stable isotopes and trace elements analysis were used for assessment of migration phenomena in five human skeletons, found in 2017 in Tepe Silveh excavation in Piranshahr, northwestern Iran. On the basis of the associated findings, these skeletons belong more likely to the Millde Islamic Periods (Seljuk era). Due to the proximity of the site to the Iran, Iraq and Turkey boundaries, this study, as the first investigation about the likely migration of the ancient occupants of this region, is of a high importance. The elemental content of both tooth and bone samples of the skeletons was analyzed by ICP-MS technique and the strontium isotopes ratio ($^{87}Sr/^{86}Sr$) and trace elements ratio (Ba/Ca and Sr/Ca) were obtained to address whether these skeletons are local or non-local. The results of strontium isotope analysis ($^{87}Sr/^{86}Sr$) showed that all the samples could be considered as non-local, where the isotopic ratios were out of local range (local mean ± 2SD). Moreover, the results of trace elements analysis proved the strontium isotope results, where the difference between the ratio of Ba/Ca and Sr/Ca in tooth enamel and bone shows the possible non-local nature of the skeletons, or in other words, it could be said surely that these people have spent their childhood in different places.

KEYWORDS: Ancient migration; Archaeological bones; Strontium isotope analysis; Tooth enamel; Trace elements analysis; Tepe Silveh; NW Iran.

1. INTRODUCTION

1.1. STRONTIUM ISOTOPIC STUDY

Strontium isotopes analysis of ancient skeletons has provided useful and exciting results in the field archaeology during the last 20 years, particularly by characterizing past human migration and mobility (Erikson, 1985; Bentley, 2006; Liritzis et al., 2020). This analysis is also a key method for reconstruction of past animal mobility, which has been successfully applied, for example, to cattle remains (Gerling et al., 2017).

Of all the isotopes that are currently analyzed in archaeological skeletal tissues, strontium isotope is one of the most effective for characterizing prehistoric human and animal mobility (Bentley, 2006). The main isotope of strontium, ^{87}Sr, is radiogenic, and as a daughter element created by decay of rubidium (^{87}Rb), forms about 7% of total strontium of the planet. Other isotopes of strontium, including ^{84}Sr, ^{86}Sr, and ^{88}Sr, are non-radiogenic (Slovak and Paytan, 2012). Strontium isotopes serve as geochemical signatures that can be used to source a prehistoric skeleton to a geologic area, depending on how mobile the individual was during his/her life (Bentley, 2006).

The idea is that strontium isotope signatures are conveyed from eroding geologic materials through soils and the food chain into the human skeleton, and since it has an atomic radius similar to that of calcium, it readily substitutes for Ca in minerals of bones and teeth (Sillen and Kavanagh, 1982; Bentley, 2006). Bone strontium isotopic ratio analysis provide a measure of the relative importance of food from each isotopic zone (Sealy et al., 1991). The measurement of strontium isotopic ratio could be the sign of where the human has grown up and lived, since strontium enters to the body via the nutrition, and during the process of bone formation or its biologic alteration, will be inserted into the bone structure (Price et al., 1994). Therefore, the amount of strontium of the bone would continuously change as the human is alive, so the measurement of strontium in the bone structure will be the sign of where he/she has lived at the last years of his/her life hood (Price et al., 1994). On the other hand, the tooth enamel is formed in early ages of childhood and then, undergoes very little changes (Hillson, 2005). So, the study of migration of human groups is based on the analysis of both bone and tooth enamel, where the difference between the strontium ratio of bone and that of the tooth will show the migration event during the life of the human (Price et al., 1994; Knudson et al., 2005; Richards et al., 2008; Alt et al., 2014; Kasiri and Karimi, 2017).

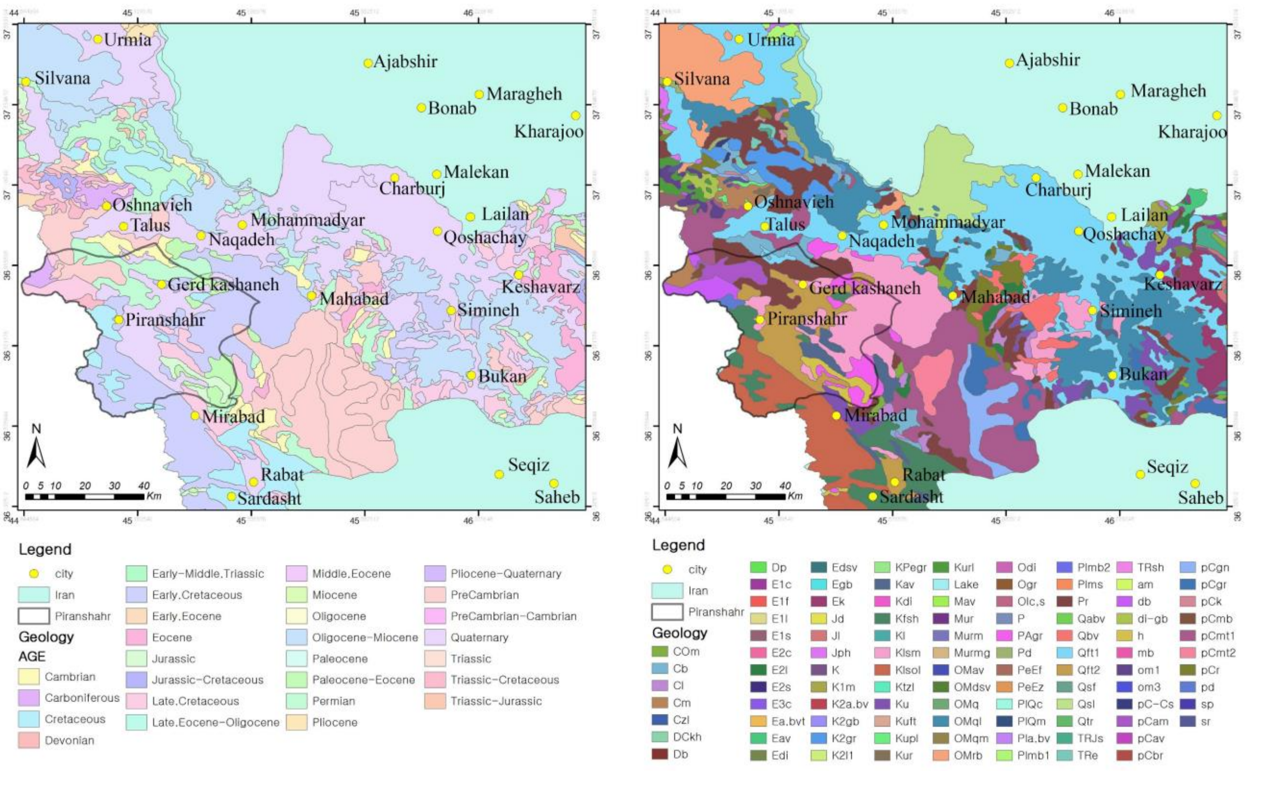

Figure 1. Geological map of Piranshahr city and the adjacent regions

Of course, the concentration of strontium and its isotope ratio in soil, surface water, plants, and thereafter in animals and human body depends almost directly on the type of the rocks of the region (Faure, 1986). Regarding the type and ages of the rocks, the ratios of strontium isotope vary at different bed rocks. Overall, the $^{87}Sr/^{86}Sr$ ratio in rocks of the continental crust varies between 0.702 and 0.750 in different regions (Bentley, 2006).

As it could be seen in Figure 1, Piranshahr city region is geologically distinguishable from the adjacent regions, and hence the geological differences directly affect the ratio of $^{87}Sr/^{86}Sr$ (Faure, 1986), the archaeological sites of this region could effectively be investigated by strontium isotopic studies.

Although the amount of strontium in plant and animal tissues are affected by many other factors, due to the miserable differences in atomic mass of strontium isotopes, its isotopic average does not change as a result of biologic processes of the body (Sillen and Kavanagh, 1982).

The local isotopic ratios could be determined by analyzing the bone samples of the same skeleton, other skeleton found at the same archaeological site, or the recent skeletons of the animals found at the vicinity of the site (Price and Burton, 2010).

To verify the results obtained from isotopic studies, the amount of trace elements of bones and teeth samples could also be measured. It has been shown that the ratios of Ba/Ca and Sr/Ca at various geographical regions are different and therefore, these ratios could also be used as a sign of mobility or migration of human (Burton et al., 2003). Moreover, Burton and Price (1999) have shown that barium and strontium exist in bone tissue as the trace elements, and their amount could reflect the variation in human diet. This fact could also be useful in migration and provenance studies (Burton et al., 2003).

In this study, strontium stable isotopes and trace elements analysis were used for assessment of migration phenomena in five human skeletons, found in 2017 in Tepe Silveh excavation in Piranshahr, northwestern Iran. Due to the proximity of the site to the Iran, Iraq and Turkey boundaries, this study, as the first investigation about the likely migration of the ancient occupants of this region, is a high importance.

1.2. ARCHAEOLOGICAL BACKGROUND OF THE REGION

During 2008 archaeological survey which have be carried out by Binandeh the settlement patterns of the region along Little Zab River Basin and Simineh Rud, dated back to the Neolithic to the Islamic era, was revealed (Binandeh et al., 2012). Excavation at Tepe Lavin should be considered as one of the important excavation project in Piranshahr region (Binandeh et al., 2012). Excavation in dam archaeological projects such as Sardasht (Fallahian and Nozhati, 2016) Silveh (Abedi, 2017) and Kanisib should be consider as the important scientific projects for better understanding of the past history of the region from Neolithic to the Islamic era.

Tepe Silveh Piranshahr, North-Western Iran

The northwestern flank of the Iranian plateau is in proximity to the Caucasian mountains and Kura River boundary of Asia Minor, Caucasia and northern Mesopotamia that together includes a region of over 100,000 km². With the current political division of the region into East and West Azerbaijan and the Ardebil provinces, the northwest Iranian plateau is referred to as Azerbaijan (Omrani et al., 2012; Abedi et al., 2014). The northwest of Iran's Plateau, in terms of its proximity to Mesopotamia, was considered by researchers, and almost simultaneously with archaeological activities in Iraq, archaeological excavation and survey have in different parts of the region. Meanwhile, Iranian scholars and missions were also surveyed in the area, and the results of these activities were the preparation of an archaeological archival publication, although scant article or book have been published (Omrani et al., 2012). Piranshahr is a city located in West Azarbaijan Province in west Iran. It is the capital of Piranshahr County. This city is the center of the traditional region of Mokrian. (Figure 2)

Special border and frontier location of Piranshahr give special importance for the region from prehistoric to contemporary era. Considering the position of the Piranshahr on the border between Iran and Iraq and its proximity to the Turkish border, it could be considered as a privileged position. As the Piranshahr plain is one of the most fertile agricultural plains in the southern part of the Urmia Lake for the formation of prehistoric sites of northwest Iran, and as respects to proximity of this region with Mesopotamia, it should be considered as one of the main entrances gate to Mesopotamia and vice-versa. The city of Piranshahr has over than 250 sites and ancient hills, of which 153 sites have been registered in four time stages (1966, 2002, 2005 and 2008), while more than 100 sites and ancient hills have been identified that have not been registered yet. The ancient sites of this city have diverse cultural courses from Neolithic to the Islamic era, in which prehistoric periods of Hajji Firuz, Dalma, Pisdeli and the Iron Age sites are predominant. Archaeological rescue project of the Silveh Dam was carried out by Iranian Center for Archaeological Research (ICAR) (952141/00/3937–1395/12/23) permission during about four months' field activities. The Silveh Dam is an earth-fill embankment dam being constructed on the Lavin River just downstream of the village of Silveh in Piranshahr County, West Azerbaijan Province, Iran. The primary purpose of the dam is interbasin transfer for irrigation. When complete, a tunnel and canals will shift water from the reservoir north to the Chaparabad area. The project will essentially transfer water from the Little Zab River basin to the Lake Urmia basin in an effort to help replenish the lake and irrigate about 9,400 ha (23,000 acres) of farmland. Construction on the dam began in 2004 and completed in 2017. The village of Silveh (where Tepe Silveh is located) and archeological sites flooded and submerged completely when the reservoir is impounded in 2017.

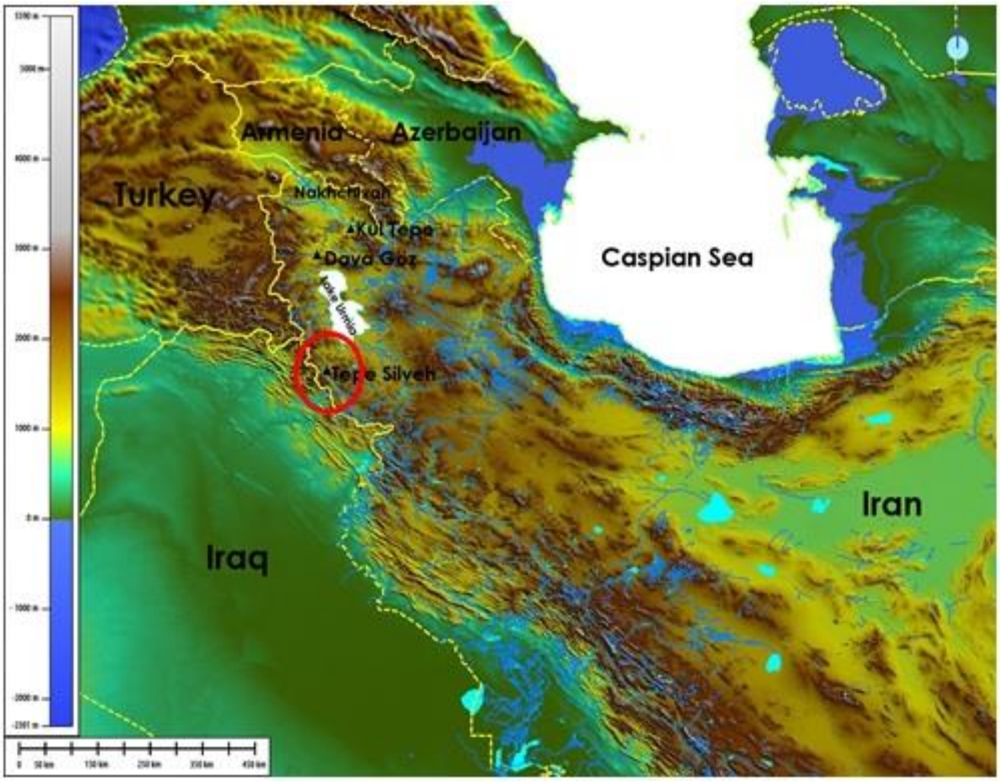

Figure 2. Geographical location of Tepe Silveh and Piranshahr, North-Western Iran

Tepe Silveh or as villager named "Tepe Sheikh Esmail Silveh" (N: 36° 48' 099'' – E: 45° 05' 937'' – altitude: 1567 m) is located exactly 100 m north of the Silveh village. Tepe Silveh is located in the center of intermountain river valley on the northern margin of the village, which has already been demolished and abandoned. As explained above, the reason for the destruction of the village was the sinking in the basin of the Silveh Dam. Seven Excavation trenches in Tepe Silveh have revealed, important materials from Early Chalcolithic Dalma (5000 BC) culture, Late Chalcolithic, Early Bronze Age culture of Hasan Ali or Nineveh V (3500- 2700 BC), Iron Age and Parthian periods. After a gap, Tepe Silveh have re-settled during Millde Islamic Periods (Seljuk era) and continued up to the late Islamic Period (Abedi, 2017) (Figures 2, 3).

According to the important location of Tepe Silveh and different occupation of the site deformation from Early Chalcolithic Dalma period to Islamic era, it should be suggested as a particularly important case study of migration, because it has been active and dynamic during different periods. Proximity of the site to the Iran, Iraq and Turkey adds to the importance of this study.

Figure 3. (Left) Tepe Silveh Piranshahr, (Center) general view from excavated trenches, (Right) graves and burials in Silveh Dam project

2. MATERIALS AND METHODS

2.1. Selection of samples

One of the most important criteria for the selection of the skeletons for isotopic studies is existence of molar teeth in good condition. It has been shown that the molar teeth structure is being completed in early ages of life hood and therefor, sampling from the first molar teeth is the basis of strontium isotope analysis (Price and Burton, 2010).

It is important to select the bone sample for signs of end-of-life. Rates of turnover for different bones have significant consequences for migration studies and should be taken into account when selecting bone samples for analysis (Price et al., 2002). The rate at which bones remodel depend upon the skeletal element and the type of bone analyzed. The diaphysis of long bones such as the tibia and femur take decades to remodel, while ribs replace their chemical constituents after only a few years (Jowsey, 1961; Jowsey et al., 1965; Parfitt, 1983; Eriksen, 1986; Hill, 1998). In this study first molar teeth and rib bones of five skeleton found during the archaeological excavation of Tepe Silveh, Piranshahr were selected (Figure 4), while their characteristics has been shown in Table 1.

Figure 4. Selected tooth and bone samples for the analysis

Table 1. Physical and archaeological characteristics of the bone and tooth samples

No.	Grave No.	Sex	Weight (g)		Dimension (cm)	
			Tooth	Bone	Tooth	Bone
1	33	M	0.435	1.666	0.81 × 1.48	1.46 × 7.78
2	41	F	0.818	3.457	0.90 ×2.00	1.39 × 9.51
3	8	M	0.528	1.694	0.92 × 1.39	0.94 × 8.66
4	27	F	0.641	2.328	0.72 × 2.07	1.92 × 8.41
5	23	M	0.722	4.830	0.70 × 2.15	1.70 × 11.60

2.2. SAMPLE PREPARATION AND ANALYSIS

Totally ten samples (one tooth and one bone from each graves) were selected for the analysis. At first, the tooth and bone samples cleaned by physical method, by a soft brush and scalpel, then all samples were washed with Milli-Q water and were dried in an oven unit at a temperature of 70 °C for 24 hours. Samples analyzed in the Kimiazi Analysis Research Institute in Tehran, IRAN.

Isotopic measurements were realized by a Perkin-Elmer ICP-MS spectrometer, model ELAN DRS-e, equipped with a multicollector detector. The instrument was calibrated by strontium carbonate isotopic standard (SRM 987), provided by National Institute of Standard and Technology (NIST). To check the measurement error of the instrument, the strontium ratio of this standard was measured ten times by the instrument, where the amount of 0.7102 was obtained at all the runs. As the exact amount of this ratio in the standard is 0.710260, the systematic error of the measurement could be considered as negligible. To minimize the measurement error, every run was repeated twice and the mean value was calculated. The amount of trace elements of the samples, strontium and barium, as well as that of calcium, was also measured during the repeated runs by the same ICP-MS instrument. In this way, the related universal standards were used for calibration of the instruments.

3. RESULTS AND DISCUSSIONS

3.1. STRONTIUM ISOTOPIC ANALYSIS

To obtain the local strontium ratio, bone samples of the site were used. This is one of the best ways to avoid mistakes caused by possible contamination of the archaeological site. The bone samples found at archaeological sites have been successfully used as the reference or mean value, reported at numerous researches (Price et al., 2002; Schweissing and Grupe, 2003; Knudson et al., 2004; Kusaka et al., 2009; Price and Burton, 2010). The strontium isotopic ratio, mean ratio of ratios and the mean ± 2 (SD), as a border of local samples, were calculated and shown in Table 2.

Figure 5 shows the isotopic values of the samples and mean value with dashed line along with the local borders (mean ± 2SD), with the vertical black lines, as if when Sr isotope ratio lay within these lines, the sample is local. Otherwise, the sample belongs to a migrant (Price et al., 2002).

Table 2. The $^{87}Sr/^{86}Sr$ ratios of the bone samples

Grave No.	33	41	8	27	23
Sample No.	1	2	3	4	5
$^{87}Sr/^{86}Sr$	0.7214	0.7118	0.7239	0.7203	0.7107
Mean	0.7176				
Standard Deviation (SD)	0.0057				

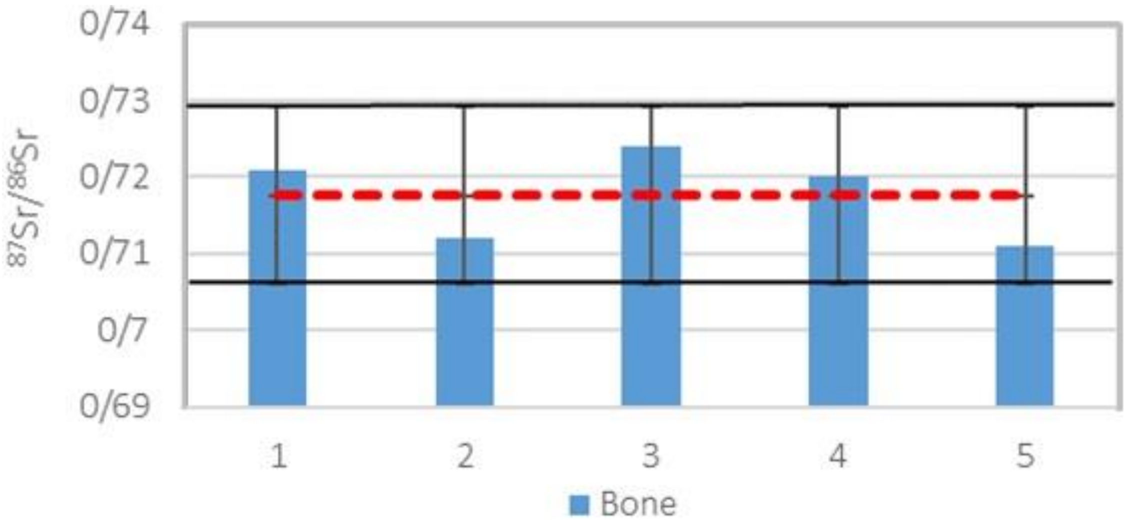

Figure 5. Strontium ratio of the bones (blue columns) along with the mean ± 2SD values (black lines) and mean value (dashed red line)

In this research, these borders were calculated as 0.7290 and 0.7062, which are the limits of local sample.

In the next step, strontium isotope ratio ($^{87}Sr/^{86}Sr$) of the tooth samples was measured, where the results were shown in Table 3.

Table 3. The $^{87}Sr/^{86}Sr$ ratios of tooth samples

Sample No.	1	2	3	4	5
$^{87}Sr/^{86}Sr$	0.7298	0.7052	0.7499	0.7331	0.7296

This shows the possibly non-local nature of the skeletons, or in other words, it could be said that these people have likely spent their childhood in different place.

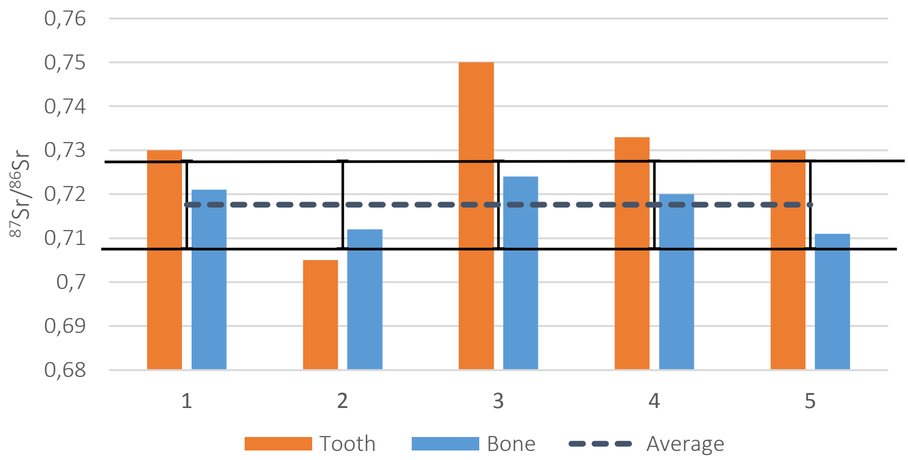

Figure 6. Strontium ratio of the bones and tooth along with the mean value

3.2. TRACE ELEMENTS ANALYSIS

To verify the results obtained from isotopic studies, the amount of trace elements of bones and teeth samples was also measured. As it was said previously, the ratio of Ba/Ca and Sr/Ca at various geographical regions are different and therefore, these ratios could also be used as a sign of mobility or migration of human (Burton et al., 2003). The ratio of Ba and Sr ions concentration, as the trace elements of bone and tooth, to that of Ca ion was measured as %. To remove big variation, decreasing the scattering, and keeping the significance of the data high, the results converted to logarithmic values (Burton and Price, 1990). Table 4 shows the results of this analysis along with the logarithmic values of these ratios at bone samples.

The ratio of these trace elements to Ca ion was also calculated for tooth samples and the obtained result have been shown in Table 4, too. To compare the ratio of these trace elements to Ca content of the bone and teeth samples, the logarithmic ratio±1SD of the measured values were also calculated. The mean and logarithmic ratio±1SD of the measured ions in bone and teeth samples have been shown in Table 5.

Table 4. Ratios of Sr/Ca and Ba/Ca of the bone and teeth samples and their logarithmic values

Sample No.	Ba/Ca (×10⁴)		Log Ba/Ca		Sr/Ca (×10⁴)		Log Sr/Ca	
	Tooth	Bone	Tooth	Bone	Tooth	Bone	Tooth	Bone
1	22.5	140.6	-2.64	-1.85	113.1	76.0	-1.94	-2.11
2	21.0	200.0	-2.67	-1.69	386.0	36.6	-1.41	-2.43
3	105.1	123.2	-1.97	-1.90	59.5	202.6	-2.22	-1.69
4	10.7	116.5	-2.97	-1.93	71.4	286.0	-2.14	-1.54
5	10.7	135.2	-2.97	-1.86	145.0	261.0	-1.83	-1.58

Table 5. Logarithmic values of trace elements ratio±1SD

Material	Log Ba/Ca ± 1SD	Log Sr/Ca ± 1SD
Bone	-1.8460 ± 0.09290	-1.8700 ± 0.38620
Tooth	-2.6440 ± 0.40851	-1.9080 ± 0.31870

To find more, a graphical comparison was realized between Sr/Ca and Ba/Ca logarithmic ratios of teeth samples and that of bone samples (Figure 7). There was a significant difference between the measured values, where the measured values of teeth were out of the range of logarithmic value ±SD of the bones, and consequently, this analysis shows that all the studied samples are not local.

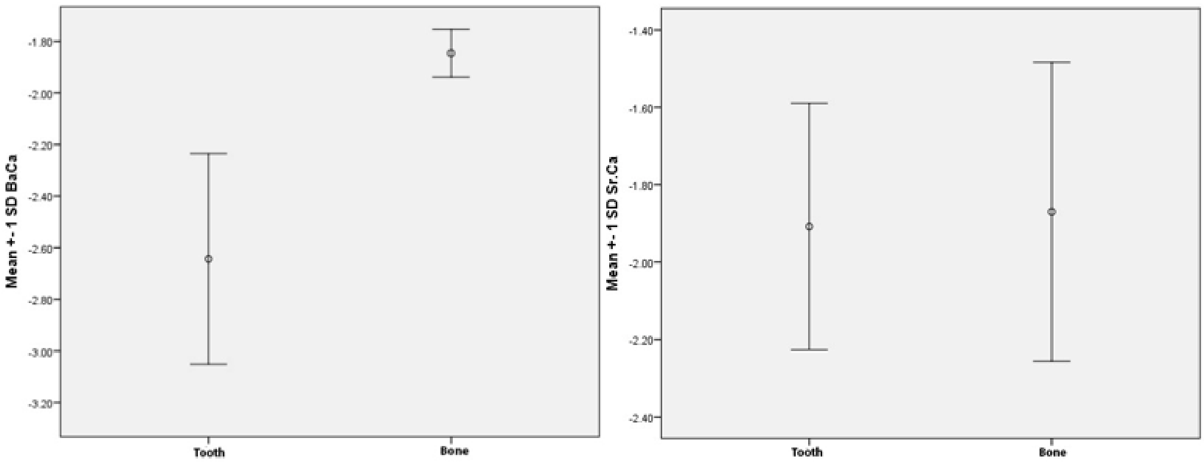

Figure 7. The Ba/Ca ratio (left) and Sr/Ca ratio (right) of the bones and tooth along with the mean value ±1SD intervals

Finally, according to the results of both methods (strontium isotopic ratios and trace elements ratios) to find out whether the studied samples are local or non-local, it could be said that all the samples are non-local, where both experiments had similar results.

4. CONCLUSIONS

The skeleton samples of Tepe Silveh, Piranshahr were successfully studied by strontium stable isotope and trace elements analysis to find out whether these skeletons are local or not. Comparing the $^{87}Sr/^{86}Sr$ results of teeth and bone samples showed that all the samples can't be considered as local. Moreover, the results of trace elements analysis proved the strontium isotope results, where the difference between the ratio of Ba/Ca and Sr/Ca in teeth enamel and bone confirmed the non-local nature of the skeletons, or in other words, it could be said that these people have likely spent their childhood in different places.

ACKNOWLEDGEMENTS

The authors wish to thank Tabriz Islamic Art University and Iranian Cultural Heritage, Handicrafts and Tourism Organization (ICHTO) for the permissions and all the supports.

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