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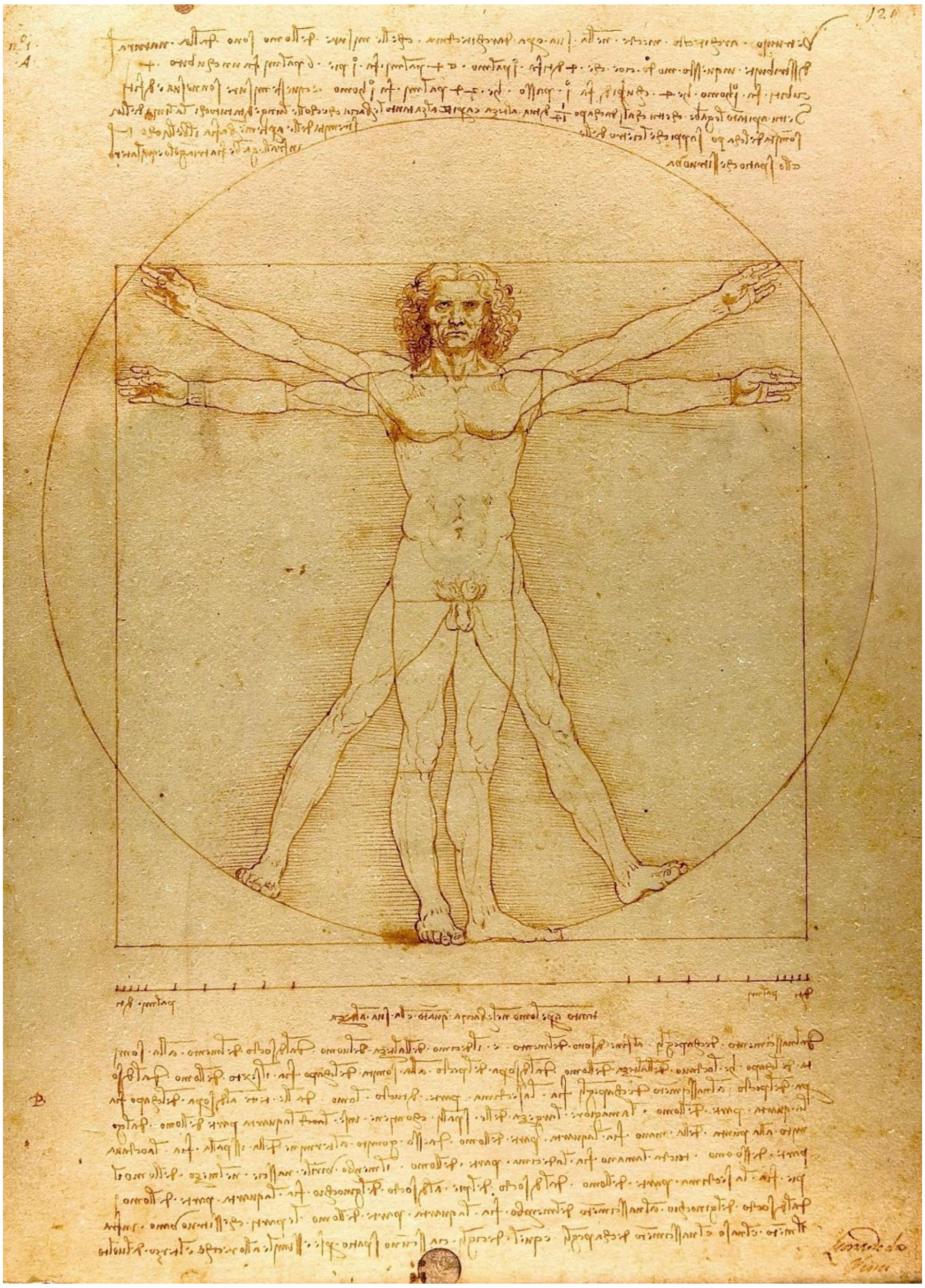

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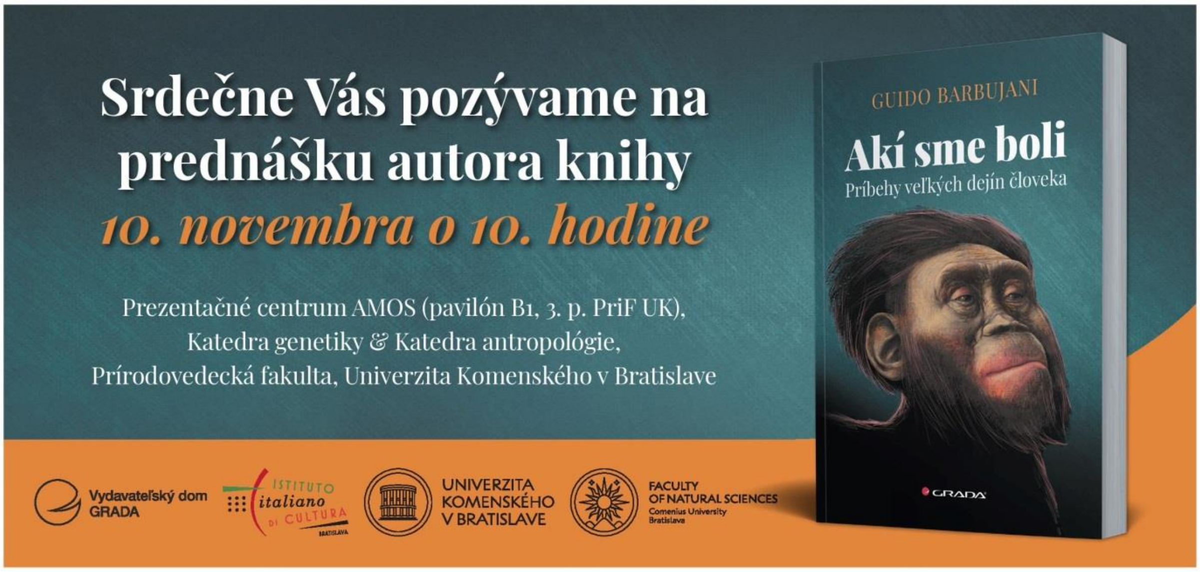
Zo života spoločnosti

Koncom septembra 2023 oslovila Katedru antropológie a Katedru genetiky Prírodovedeckej fakulty UK pani Adriana Šulíková z Istituto Italiano di Cultura (ITC, Taliansky kultúrny inštitút) s ponukou, že v novembri príde na Slovensko prezentovať preklad svojej najnovšej knihy profesor Guido Barbujani. Profesor Barbujani pôsobil na Stony Brook University v New Yorku, na talianskych univerzitách v Padove a v Bologni, a od roku 1996 je profesorom genetiky na Fakulte prírodných vied, životného prostredia a prevencie Univerzity Ferrara. Profesionálne sa venuje genetike a problematike pôvodu a evolúcie ľudských populácií, čomu sa venuje aj jeho najnovšia populárno-náučná kniha s názvom *Akí sme boli*, ktorú prišiel na Slovensko propagovať. Na Slovensku mal dve prednášky – 9. novembra 2023 sa ním konala diskusia v priestoroch Slovenského národného múzea a 10. novembra mal prednášku na tému ľudskej evolúcie a variability v prezentačnom centre AMOS na našej fakulte. Po prednáške bola bohatá diskusia, a keďže sa kniha priamo aj u nás predávala, prebehla aj autogramiáda.

Radoslav Beňuš



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PALEOPATHOLOGICAL ANALYSIS OF THE PÉCSVARÁD PANNONIAN AVAR BURIAL SITE (HUNGARY) DATED TO THE 9th CENTURY

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Abstract: At the Pécsvarád, Pannonian Avar burial site, a collection of 27 individuals was paleopathologically examined: nine males (M), ten females (F), seven children (CH), one unidentified individual (N). Traumas occurred in three cases out of 27 individuals (11.1%): an execution, a serial rib fracture and an unhealed fracture in the parietal region. Workload was found in 11 instances out of 27 (40.7%), with maximum strain of the skeletons on the spine, shoulder joints and phalanges. Congenital anomalies occurred in nine cases out of 27 individuals (33.3%), they were present in form of craniosynostoses, dental anomalies and vertebral fusions. Anaemia accurring as cribra orbitalia was discovered in 12 cases out of 27 individuals (44.4%). Scurvy, vitamin C deficiency, was recognized in 13 cases out of 27 (48.2%) through porotic lesions on the palate and the sphenoid bone. Dental disabilities occurred in eight cases out of 27 (29.6%), they were usually represented by tooth loss in life due to periodontitis. Infections occurred in five cases out of 27 (18.5%). In one instance, it was brucellosis and one instance was meningitis. A benign tumor, meningioma, was found in one case out of 27 (3.7%).

Key words: Avars, execution, craniosynostosis, brucellosis, meningioma, Central Europe

Introduction

The burial site was situated to the north-east of Pécsvarád, east of the Budapest – Pécs motorway, where the roads to Lovászhetény, Nagypall and Péczvárad meet. The site was localized by Attila Kiss in 1967 (Kiss 1977). Brickwork and corresponding clay pits still visible today were used for this purpose (Fig. 1). Only 30 graves were explored during the rescue excavation at Pécsvárad-Gőztéglagyár. These graves represent only a small, late buried group (9th century) withing a large cemetery of the Avar Period. The dead were buried in extended supine position with forearms extended beside the body (Kiss 1977). The burial site was uncovered by J. Dombay between October 1st and 10th, 1942. The archaeological material was registered under inv. nos. 1942, 3., 1-50 in the catalogue of the Department of Archaeology of the János Pannonius Museum (JPM) in Pécs. Skeletal material was registered under inv. no. 55.131.56.5. in the anthropological collection of the same museum.

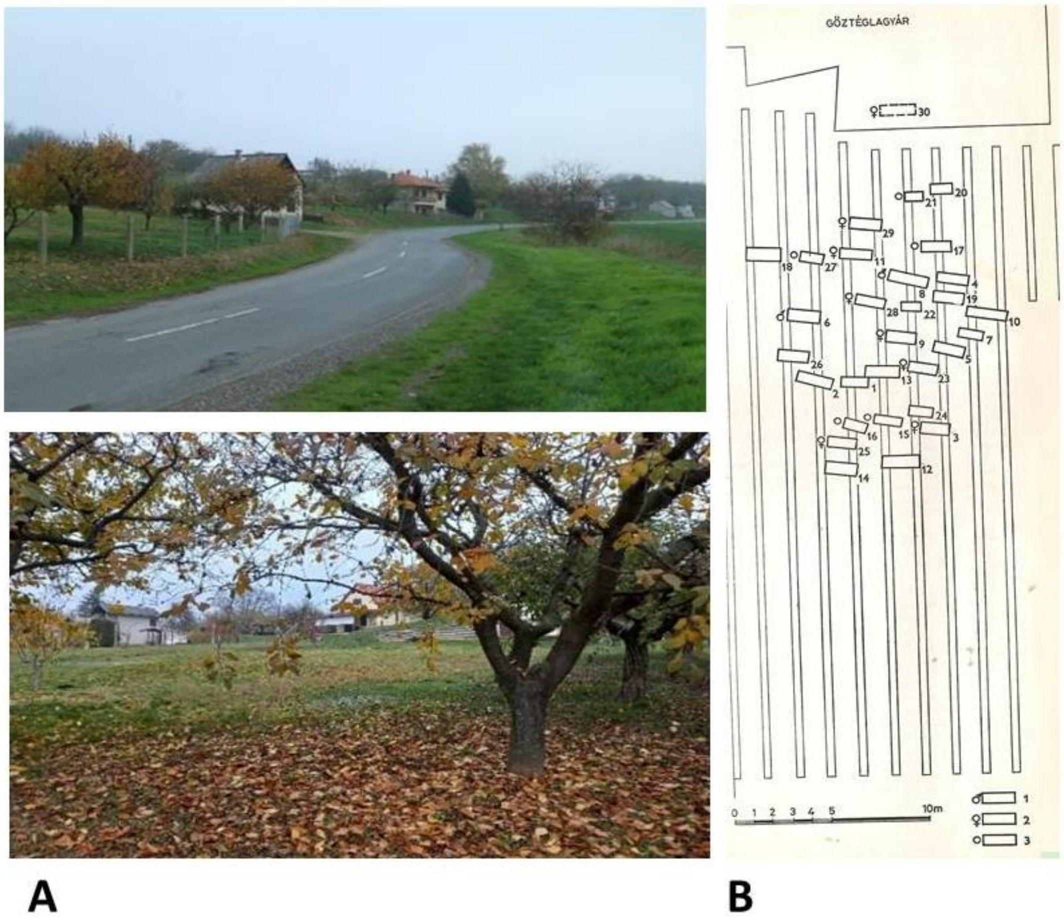

Fig. 1: A) Pécsvárad-Gőztéglagyár (N46,1576517° E18,4349148°). B) Plan of the cemetery (Kiss 1977, fig. 52; 1/male, 2/female, 3/ child)

Material and methods

The basis of the paleopathological study was the standard estimation of sex and classification of individuals into individual age categories (Stloukal et al. 1999, Drozdová 2004). At the Pécsvarád burial site, a collection of 27 individuals was paleopathologically examined: nine males (M), ten females (F), seven children (CH), one unidentified individual (N; tab. 1), together with the bone remains of several animals (horses and sheep).

Palaeopathological findings were assessed mainly according to the criteria of Steinbock (1976), Ortner and Putschar (1981), Vyhnánek (in Stloukal et al. 1999), Horáčková et al. (2004), Smrčka et al. (2009) and Lewis (2018). The basic investigative methods of paleopathological diagnosis were mainly detailed macroscopic study.

Table 1: Age categories

Sex	1-10 years	11-20 years	21-40 years	41-60 years	over 60 years
Male	x	x	5	3	1
Female	x	2	4	1	3
Child	6	1	x	x	x
Unidentified	x	1	x	x	x
Total	**6**	**4**	**9**	**4**	**4**

Results

Paleopathological Analysis

In **grave no. 1,** inv. no. 55.130 (skeleton), 55131(skull), a 14 – 20-year-old woman was inhumed. The woman had an elongated, dolichocephalic skull with unfused sutures. The maxillary teeth exhibit minimal tooth wear, the third molars are unerupted. There are cribra formations in the pterygoid fossa indicative of scurvy (Lewis 2018). There are also signs of scurvy around the foramen magnum. In the right parietal region, there is an unhealed defect of 70 x 50mm, which extends over the sagittal suture. From this, a fracture of 65 mm runs to the left into the left parietal region, and another fracture of 60 mm extends to the right into the temporal and occipital regions where there is another defect of 60 x 35 mm. Both defects appear to have been incurred perimortem by a blunt impact from behind with a spherical object to the right temporal region. On testing, the defect in the parietal region was found to correspond to the size of an axe hammer (from an 8^{th} - 9^{th} century Early Christian mausoleum, JPM) 55 x 30 mm in size (Fig. 2). A right-handed assailant, probably on horseback, attacked the back of the young woman's skull with an axe. The axis of the defect is situated at 60 degrees from the sagittal suture, i.e. from the vertical axis of the skull.

Fig. 2: Unhealed defect in a woman aged 14-20, grave no. 1 (A). Types of Avar axes with hammers from the 9^{th} century (B). Recostruction of the injury (C).

In **grave no. 2** (inv. no. 55.132) a man, aged 20 – 40, with a pentagonal skull was buried. The sutures on the skull are well preserved. The maxilla has a high-arched palate, with grade 2 of tooth wear. In the mandible, the right first molar (M1) fell antemortem. The individual was probably right-handed, with greater loading of the right upper extremity. This is inferred from the size of the clavicle on the right, which is more massive than the left one (Fig. 3). In the axial skeleton, the upper vertebra in the sacral bone is attached only from 1/3. The promontory, the upper part of the sacrum, is anteriorly fused in 1/3 with the other sacral bones.

In **grave no. 3** (inv. no. 55.147) a woman, aged 30 -- 40, was buried. Her skull sutures are well preserved. Green staining from Cu ions was found near the foramen magnum on the left side and behind the mandibular ramus on the right. On the skull, we find signs of scurvy, vitamin C deficiency, occurring in the form of *porotic lesions* on the palate, right pterygoid fossa (less on the left), and around the foramen magnum (Fig. 4).

Fig. 3: The more robust right clavicle compared to the left one in grave no. 2

Fig. 4: Signs of scurvy in grave no. 3 (woman, aged 30-40)

In **grave no. 4** (inv. no. 55.133) a man, aged 40 - 60 years, was found with a boat-shaped skull, *scaphocephaly*. It is a congenital defect, *craniosynostosis* (Barnes 1994, 2012), caused by the premature closure of the sagittal suture. The coronal and lambdoid sutures are not fused. The skull continued to grow anteriorly and posteriorly, thus getting a boat-like shape (Fig. 5). In the orbits, bilaterally, there are clusters of holes, *cribra orbitalia* type 2, indicative of ongoing anaemia. The teeth in the maxilla were lost postmortem, teeth in the mandible behind the second premolar were lost antemortem. The right side of the mandible is missing.

Fig. 5: Scaphocephaly in grave no. 4 (man, aged 40-60)

In **grave no. 5** (inv. no. 55.134) a man, aged 40-60, was inhumed. In the central part of the palate, there is a rounded bony protrusion, *torus palatinus*. There are also visible *porotic lesions* on the palate, signs of vitamin C deficiency, scurvy. Signs of scurvy are also visible elsewhere on the skull, for example in the pterygoid fossa of the sphenoid bone, but also on the acromion of the scapula. Changes in the oral cavity, on the jaws, may also be related to vitamin C deficiency. In the mandible, antemortem loss of teeth occurred (right 4, 5, 7; left 4, 5, 6, 7) and there is a large abscess near the first molar. In the maxilla, antemortem tooth loss occurred from the second premolar (P2) towards the back of the mouth on the left. The alveolus exhibits an increase in bony mass, periostitis. Signs of brucellosis could be identified in several places on the man's skeleton in grave 5.
On one of the upper ribs, bead-like periostosis was found. Another rib exhibited striated periostosis at the attachment to the sternum. The 12th thoracic vertebra, Th12, exhibits a defect (usura) of 10 mm

in diameter on its upper surface. On L2, L3, there are osteophytic rims – on L2 in the lower part of the vertebral body, and on L3 in the upper part of the vertebral body. On the upper surface of L4, there is a large usura of triangular shape with sides of 25 mm x 20 mm x 20 mm with signs of healing. On L5, on the upper surface of the vertebral body, there is a crescent-shaped usura defect of 35 mm in length, 15 mm wide, also with signs of healing (Fig. 6). The mentioned man suffered from *brucellosis*, an anthropozoonosis transmitted through the vaginal secretions of goats. The man with poor grave goods, an iron knife in his right hand, perhaps a servant or slave inhumed on the edge of the burial site, was probably in contact with a herd of animals.

Fig. 6: Signs of brucellosis in grave no. 5 (man, aged 40-60)

Fig.6: Signs of brucellosis in grave no. 5 (man, aged 40-60)

In **grave no. 6** (inv. no. 55.135) a man, aged 20-40, was buried. He had open sutures on his skull. There were type 1 *cribra orbitalia* in his orbits. On the skull, in several areas there were signs of vitamin C deficiency, scurvy. Cribra formations were found in the palatal plates of the maxilla, including an atrophy of the alveolar ridge and tooth loss in life, from the right first premolar to the back in the upper jaw. In the mandible, antemortem tooth loss occurred from the left first premolar to the back, and there were cribra formations on the sphenoid bone with prevalence in the pterygoid fossae. On the base digital phalanges 1.;2. and 4.;5. of the young man, there were bone rims, caused by strain on the short muscles perhaps during the stretching of a reflex bow or when making nets (Fig. 7).

In **grave no. 7** (inv. no. 55.136), a child – Infans I (about 3 years old) was inhumed. In the palatal region, there are cribra formations indicative of vitamin C deficiency, scurvy. On the endocranium, in the area of *protuberantia occipitalis interna*, there is periostitis along the sinus probably caused by meningitis (Fig. 8). The right temporal bone and right mandible regions are stained with Cu ions.

Fig. 7: Bone rims on phalanges in grave no. 6 (man, aged 20-40)

Fig. 8: Periostitis around the *protuberantia occipitalis interna* of the 3-year-old child in grave no. 7

In **grave no. 8** (inv. no. 55.137) a man (aged 40 - 60) was inhumed. He lost his teeth antemortem, there are *cribra* in the alveoli of the maxilla, as well scurvy with traits on the palate (Fig. 9), on the back of the sternum, on the wings of the sphenoid bone, and in the pterygoid fossa. The teeth in the mandible were also lost during the individual's life.

Fig. 9: Signs of scurvy in the upper jaw in grave no. 8

In **grave no. 9** (inv. no. 55.138) a woman (over 60 years of age) was lying. The sutures on her skull are fused. The left side is stained green from Cu ions, from earrings. In the mandible, there is a rotated cuspid. She also has cribra formations on the palate and sphenoid bone. There is spondylosis of 1 - 2 mm on the thoracic spine.

In **grave no. 10** (inv. no. 55.139) a man (aged 30-40) was inhumed. There is a congenital dental anomaly in the maxillar area, cusp of Carabelli on upper right M2. There are rims on proximal phalanges, which may be indicative of the usage of a reflex bow, or making nets, straining the short muscles of the hand. His left patella exhibits bone apposition (with significant periostal bone growth in *m. quadriceps femoris*; Dungl 2005, p. 982-991), probably caused by excessive strain of the left leg during extension, stretching the knee. There is also periostitis in the tibiae.

In **grave no. 11** (inv. no. 55.140) a woman (aged 14-20) is buried. The sutures on this woman's skull are preserved. In the lateral parts of both orbits, there are type 2 *cribra orbitalia*. The skull also shows signs of scurvy in the lower part of the pterygoid fossa. There is calculus on the teeth; the necks of the teeth in the maxilla and mandible are exposed. Greater tooth wear is visible on the front teeth up to the canines. In the mandible, there is mesial caries anteriorly on the left M1. In the spine, there is a *congenital bone block of thoracic vertebrae* (Fig. 10A), which are fused due to ossification of the ligaments on the anterior part of the vertebral bodies. On the dorsal side, unfused vertebral bodies can be seen (Fig. 10B). There is spondylosis gravis on the lumbar spine, the osteophyte on the left is 17 mm in size and the one on the right is of 13 mm. On the sacrum on the right side, there is an osteophyte of 18 mm projecting towards the last lumbar vertebra.

Fig. 10: Congenital bone block of thoracic vertebrae in grave no. 11 from right side (A), dorsal side (B)

In **grave no. 12** (inv. no. 55.141) a man (aged 30 - 40) was inhumed. His skull is in fragments, his teeth exhibit cervical caries. The ribs as well as the spine are porotic. The skeleton lay on the edge of the burial site and at a depth of 80 cm, so we assume that the man was a servant (or a slave).

In **grave no. 13** (inv. no. 55.142) a woman (aged 40 - 50) was buried. On the skull, in the right orbit, there are type 2 *cribra orbitalia*. There are signs of scurvy in the palate and around the foramen magnum, manifested by cribra formations. The teeth in the maxilla exhibit grade 2 tooth wear; in the mandible tooth wear is found on the molars, mostly on M1. Lower lumbar vertebrae exhibit fish vertebrae indicative of osteoporosis and Scheuermann's disease.

In **grave no. 14** (inv. no. 55.143) a woman (over 60 years of age) was buried. On her skull, in the right orbit, type 2 *cribra orbitalia* can be seen, the left orbit has not been preserved. Teeth were lost postmortem. There are signs of scurvy in the palatal region, however they cannot be verified at the base of the skull. It has not been preserved. The patellae of the woman's left and right lower limbs exhibit bone apposition (Dungl 2009). Since the quadriceps femoris muscle, which encases the patella, is involved in knee extension, it can be assumed that the woman worked in a squatting position. This was confirmed by the marked areas on the posterior aspect of the tibiae, at the edge of surfaces articulating with the talus, *facies articularis inferior*. A symmetrical area articulating with this surface was also marked on the talus in the region of *processus posterior tali*.

In **grave no. 15** (inv. no. 55.144) a child (Infans I - up to six months of age) was lying. The child suffered from anaemia, there are cribra formations in the right orbit. The left orbit has not been preserved. At the same time, the child developed vitamin C deficiency, *scurvy*, in several localizations in the form of *cribra* in the palatal region, including the nasal cavity, as well as in the occipital region of the skull, and in the neck of the right femur.

In **grave no. 16** (inv. no. 55.145) a child (Infans I) was inhumed. Type 2 *cribra orbitalia* was found in both of the child's orbits. The child suffered from anaemia. At the same time, the child suffered from a lack of vitamin C, scurvy. This was manifested by cribra formations on both palatal plates and on the neck of the right femur.

In **grave no. 18** (inv. no. 56.1) an unidentified adult individual (aged 20 - 30) was found. The individual suffered from anaemia, with type 2 *cribra orbitalia* found in both orbits. On the skull, signs of vitamin C deficiency, scurvy, manifested by pitting on the palate and wings of the sphenoid bone can be seen. An *unhealed serial rib fracture* was discovered in this individual. Three ribs were fractured: two ribs on the right, which were fractured almost in the middle, on the inner side, between the 5th and 7th ribs. On the left side, one rib is fractured, also between the 5th and 7th ribs and almost in the angle on the inner side (Fig. 11).

Fig. 11: Rib fracture in grave no. 18 (A), rib fracture (B)

In **grave no. 19** (inv. no. 55.146) a man (aged 20 - 30) was found with nothing abnormal discovered.

In **grave no. 20** (inv. no. 56.2) a woman (aged 20 - 40) who suffered from anaemia was discovered. In the left orbit, we found type 3 *cribra orbitalia*, and type 2 in the right one (Fig. 12). Tooth wear was mostly concentrated on the molars of both the maxilla and mandible. The woman had mostly loaded her left upper limb, which was evident from the massive left clavicle (Fig. 13).

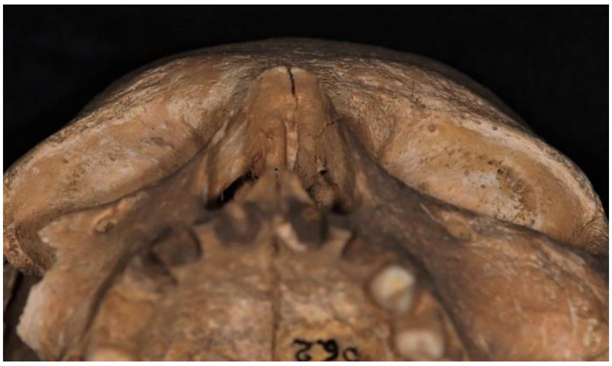

Fig. 12: Cribra orbitalia (grave no. 20)

Fig. 13: Massive left clavicle, probably due to greater work strain (grave no. 20)

In **grave no. 21** (inv. no. 56.5) most probably a girl (Infans I, age 4 -7 years) was inhumed. She had an elongated skull with preserved sutures, sutural bones in the left lambdoid suture. She suffered from anaemia, we found type 2 *cribra orbitalia* in both orbits, the right orbit was partially damaged.

In **grave no. 22** (inv. no. 55.148) an individual (Juvenis, under 20 years of age) was lying. There are signs of Cu ions on the pelvis and a long bone.

In **grave no. 23** (inv. no. 55.149) a woman (aged 20 - 40) was buried. The individual was without any visible pathological lesions.

In **grave no. 24** (inv. no. 56.3) a girl (assuming by her mandible and earrings, Infans II, 7- to14-years-old) was buried. The skull of a girl with suggested *bathrocephaly* has all the sutures. The green staining from Cu ions around the mastoid processes indicate possible earrings. There are type 1 *cribra orbitalia* in both orbits. Vitamin C deficiency, scurvy, is manifested on the on the right side of the sphenoid bone in the pterygoid fossa. On the left parietal bone, there is a 45 mm long *fracture* (Fig. 14) which continues as a fine fissure onto the frontal bone in the extent of 25 mm. On a fragment in the occipital region, *periostosis* can be seen which could be indicative of meningitis related to the unhealed fracture, which could have been the cause of death.

Fig. 14: Fracture of the parietal region on the left (grave no. 24)

In **grave no. 25** (inv. no. 55.150) a woman (over 60 years of age) with a skull of pentagonal shape was buried. In the maxilla, antemortem tooth loss occurred from the premolars towards the back of the mouth. In the mandible, there is postmortem tooth loss, with *an abscess* in the lower right M2 region (Fig. 15). On the left side, there is an impression of a meningeal vessel verging into Pacchionian granulations with increased vascular arborization in the vicinity - indicating a meningioma (Campillo 1977). In the lumbar spine, there is spondylosis with osteophytes exceeding 4 mm, including the sacrum.

Fig. 15: Abscess at M2 on the right side (grave no. 25)

In **grave no. 26** (inv. no. 55.151) a man (over 60 years of age) was buried. This man has a congenital defect, an open sacral canal (*canalis sacralis apertus*; fig. 16).

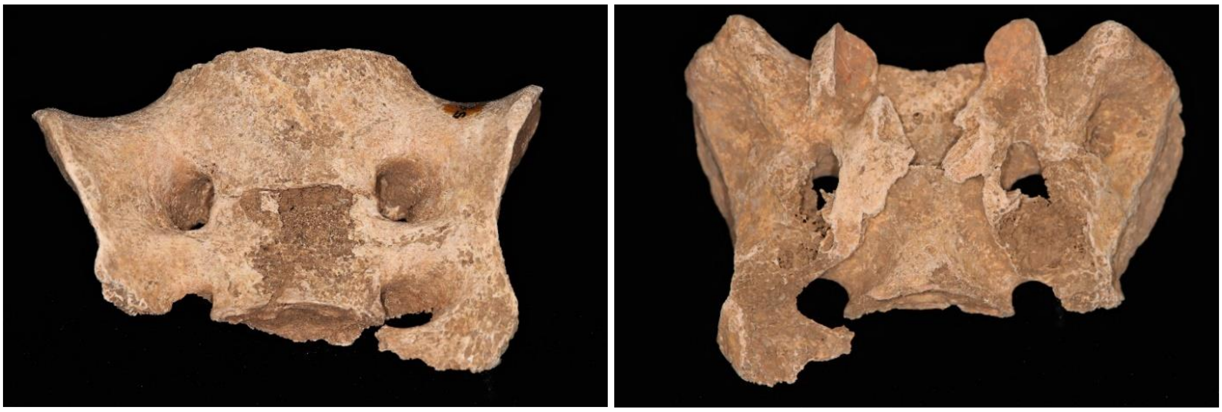

Fig. 16: Canalis sacralis apertus (grave no. 26), frontal view (A), back view (B)

In **grave no. 28** (inv. no. 56.4) a girl (Infans II, 7- to 14-years-old) was found. The girl has a pentagonal skull and all sutures are open. She suffered from anaemia, there are obvious bilateral type 1 *cribra orbitalia* in the orbits. There are signs of vitamin C deficiency, scurvy, in the form of *cribra* on the palate, the sphenoid bone and around the *foramen magnum.* There are sutural bones in the lambdoid suture bilaterally.

In **grave no. 29** (inv. no. 55.152) a woman (aged 20 - 40) was found. She had a congenital spinal defect - lumbarisation of the sacrum. The lateral process, *processus costalis*, on the left side at L5 is enlarged and connected to the left side of the sacrum by a false joint (Fig. 17). The proximal hand phalanges show indications of bone rims, up to 1 mm, pointing to increased strain on the short muscles of the hand, lumbricals and interosseous muscles, perhaps during the process of weaving textiles.

Fig. 17: Sacrum and L5 with processus costalis on the left (grave no. 29), anterior view (A, B), posterior view (C)

Traumas occurred in three out of 27 cases (11.1%). In grave no. 1 it was (F 14- to 20-year-old) an execution, interpersonal violence, inflicted with the blunt part of a war axe by a right-handed horseman. In grave no. 18 (N 20- to 30-year-old) a serial rib fracture was discovered. In grave no. 24 there was a child (7- to 14-year-old) with an unhealed fracture in the parietal region, which was probably the cause of meningitis. **Workload** was found in 11 out of 27 instances (40.7%) with maximum loading of the skeletons on the spine, shoulder joints and hand phalanges. Excessive straining of short muscles led to the formation of bone rims on phalanges in 2/27 (7.4%) instances, probably during weaving or net making (eg. grave no. 6; M 20- to 40-year-old). Strain on the spine with spondylotic ostephytes was found in 3/27 (11.1%) cases. Excessive enlargement of the outer part of the clavicle was discovered in 2/27 (7.4%) individuals, as well peristeal reaction on the patella persisted as the bone apposition type due to permanent microtraumatisation in 2/27 (7.4%) instances (Dungl 2005, p. 981-992). **Congenital anomalies** occurred in nine out of 27 cases (33.3%), in the form of craniosynostoses, cranial sutural bones, dental anomalies, and vertebral fusions. In grave no. 4, a 40- to 60-year-old male had a boat-shaped skull, scafocephaly. In grave no. 11, a female, aged 14-20, had a congenital fusion of thoracic vertebrae caused by ossification of the anterior ligaments of the vertebral bodies. In children, girls in graves no. 21 (4- to 7-year-old) and no. 28 (7- to 14-year-old), sutural bones were present. **Anaemia** in the form of *cribra orbitalia* (Møller-Christensen and Sandison 1963) was discovered in 12 cases out of 27 individuals (44.4%), where type 1 occurred three times, type 2 occurred eight times and type 3 once. It is presumed that this type of anaemia is caused by iron deficiency with prevalence of 20% (Hengen 1971). **Scurvy**, vitamin C deficiency (Lewis 2018), was recognized in 13 out of 27 cases (48.2%) through cribra formations on the palate, the sphenoid bone, in the region of the skull and on the femur. **Dental disabilities** occurred in eight out of 27 cases (29.6%), usually it was tooth loss in life due to periodontitis caused by vitamin C deficiency. **Infections** occurred in five out of 27 cases (18.5%). In one instance out of 27 (3.7%) it was *brucellosis* (grave no. 5; M 40- to 60-year-old; Adler 2000, Ortner 2003) and one instance was *meningitis* (grave no. 24; CH 7- to14-year-old).

Discussion

The Introduction of Milk in the Human Diet and Brucella Melitensis

Milk was added to the diet already in the Neolithic and presented an important innovation. At the same time, it became a key factor in the transmission of zoonoses to the human population. Archaeological research has proved that milk started being used in the Middle East in the eighth millennium BC. Direct evidence in the form of preserved organic remains on ceramics from Anatolia are dated to the seventh millennium BC (Evershed et al. 2008). Goat populations presented a suitable reservoir for brucellosis. Goat farming spread in mid-seventh millennium BC, when in most Neolithic locations male goats would be killed off. However, this focus on meat production brought with it the distribution of brucellosis. Brucellosis is spread by female goats through their vaginal secretions. In villages, the mixing of goat herds led to the spreading of brucellosis. The pathogens could stop spreading and vanish in small villages rather than the larger ones (Fournié et al. 2017). In terms of differential diagnosis, it is difficult to differentiate between tubercular and brucellar lesions (Adler 2000).

A benign tumor, meningioma (Campillo 1977, Smrčka et al. 2003) was found in one case out of 27 individulas (3.7 %) (in grave no. 25; female over 60 years of age).

Social Relations, Placement within the Cemetery and Diseases

Families, or clans, form groups at the burial ground. Individuals with no grave goods, in a total of nine out of 27 cases (in graves no. 1, 2, 7, 12, 16, 18, 19, 20, and 26) comprise 33.3% of the inhumed individuals. These individuals were interred on the edges of family groups. In the individual from grave no. 5 (M 40- to 60-year-old), brucellosis was identified. The brucellosis was also found in the Avar Vősendorf/S1 (Pany-Kučera et al. 2017). This was transmitted by goats and this individual probably herded animals (Evershead 2008). Based on the execution, the young woman (grave no. 1) was not spared, but she was later given the dignity of a funeral.

Conclusion

The original pathological findings on the 9th century Avar skeletal remains of 27 individuals from Pécsvarád provide insight into the congenital anomalies 9/27 (33.3%) of spinal defects and dental diseases that were common in this period and locality, as well as diseases caused by non-specific infections occurred in 5/25 (18.5%), vitamin deficiencies and malnutrition. In terms of bone pathology, scurvy (48%), anaemia, *cribra orbitalia* (44.4%), congenital anomalies (33,3%) and dental disabilities (29.6%) predominated in the cohort, followed by nonspecific infections (18.5%) and trauma (11.1%).

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EFFECT OF DIRECT SUNLIGHT ON LATENT FINGERPRINTS

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Abstract: Environmental factors can affect the quality of latent fingerprints left at a crime scene. We observed the effect of direct sunlight on latent traces. In total, we evaluated 288 latent fingerprints that were exposed to direct sunlight and made visible with magnetic powder at weekly intervals. After evaluating the average number of minutiae, we found that latent traces are of high quality and usable for personal identification even after seven weeks of exposure of latent fingerprints to direct sunlight.

Key words: dermatoglyphics, environmental factors, degradation of latent fingerprints, personal identification, forensic anthropology

Introduction

Friction ridge skin possesses distinct characteristics that remain unchanged from before birth to decomposition after death. When it comes into contact with a surface, these distinctive features can leave behind impressions containing matching details. Through the analysis, comparison and evaluation of the two fingerprints, a competent examiner may determine to confirm or deny a match for personal identification. If there is a significant amount and quality of detail present, the examiner can identify or exclude a specific individual (Wertheim 2011).

Volar skin consists of two primary layers: the outer layer, known as the epidermis, and the inner layer, referred to as the dermis. The patterns of ridges and furrows found on friction skin reflect the intricate structure of the underlying epidermis. Specifically, the basal layer of the epidermis on friction skin possesses folds that extend into the dermis, aligning with the ridges and furrows observed on the outer surface of the epidermis. The growth of primary ridges during development can result in many changes. The fingers grow rapidly, as a result of which the existing papillary lines separate. Due to the tendency of the surface to be constantly striated, new papillary lines are formed. The new papillary lines move away from the existing primary lines due to growth. These lines, together with the furrows, whose anatomical function increases sensitivity to touch and friction, are the basic characteristics of dactyloscopy (Sharma et al. 2018, Wertheim 2011, Wertheim and Maceo 2002).

The emergence of these unique characteristics has an important role in personal identification. Fingerprints, due to their uniqueness and immutability, are considered as one of the most important forms of evidence. They can be found on a variety of common objects, as well as on objects present at a crime scene. The uniqueness of fingerprints is determined by minutiae (second level identification markers; Abhishek and Yogi 2015).

Minutiae are used for personal identification due to their high variability. Individual uniqueness is affected by the high number of minutiae and their random distribution within the papillary terrain. The distribution of identification characteristics on fingerprints has sufficient discriminatory power to determine the identity of an individual (Abhishek and Yogi 2015, Šimovček et al. 2011, Pospíšil 1974).

Fingerprints are often exposed to conditions that can degrade them. This fact complicates the work of professionals. Scientists and investigators have not established precise parameters and metrics of degradation that can reliably indicate and demonstrate the level of degradation over time. The combination of light and heat has a significant impact on the visual degradation of latent traces. Each possible combination of factors affects the rate of chemical and visual degradation differently, making the determination of the time of latent traces more challenging. Exposure of latent fingerprints to light by itself may not have the same degrading effect as when it is combined with a certain temperature of the environment in which the latent traces are found. If the latent fingerprints are in a light, warm and less humid environment, the level of degradation is lower. If the relative humidity of the environment is higher, latent fingerprints will be more visually degraded (Richmond-Aylor et al. 2007, De Alcaraz-Fossoul et al. 2021a)

A non-porous surface has a positive effect on the quality of latent traces. Despite the evaporation of sweat substance from latent traces left on non-porous surfaces, the results of dactyloscopic trace degradation are more favorable compared to latent fingerprints left on a porous surface. Magnetic dactyloscopic powder is the most suitable method to visualize latent traces that have been exposed to direct sunlight (De Paoli 2010, Gürüz et al. 2015, De Alcaraz-Fossoul et al. 2021b).

Material and methods

The evaluated set represents 288 latent fingerprints that were exposed to direct sunlight at different time intervals over a period of one week to seven weeks. We left contact latent fingerprints on glass plates. All glass plates were washed with clean water to remove dirt before leaving latent traces. Glass plates with latent fingerprints were stored in a transparent plastic container to prevent contamination by dust or other particles. This container was opened only during the removal of the glass plates, which were subsequently visualized. We left 36 latent traces on eight glass plates. One glass plate served as our control sample. We then exposed the glass plates with latent traces to direct sunlight. Each week we visualized one glass plate with latent prints exposed to direct sunlight. To visualize the latent traces, we used a magnetic silver-gray Hi-fi dactyloscopic powder. This powder was applied with a magnetic dactyloscopic brush MaxMag (15 cm), which is a magnetic brush with a strong magnet, for working with larger amounts of powder. We removed visualized fingerprints on adhesive tape, which we always pressed with sufficient force on the visualized print. In a slow motion, we peeled off the tape along with the visualized fingerprint from the glass pane and transferred them to the paper.

The visualized latent traces were scanned at a resolution of 1200 dpi. The scanned fingerprints were evaluated in Preview 11.0 (1048) by Apple Inc. The number of minutiae in the control sample and on the latent fingerprints of the distal phalanges exposed to this environmental factor at each time interval were evaluated. To evaluate the number of minutiae on the degraded latent fingerprints, we were assisted with a sample fingerprint (Fig. 1).

Fig. 1: The evaluated minutiae on the sample fingerprint

The temperature of the environment in which latent fingerprints were left was measured with an indoor thermometer Thermopro TP357 (°C). Light intensity (LUX) was measured with a Uni-t UT383S (Digital light meter).

Microsoft Office Excel 2023 was used to process the data obtained. Statistical analysis of the data was performed using IBM SPSS Statistics 26 software.

For the statistical analysis, we evaluated the descriptive statistics of the number of minutiae on degraded latent traces exposed to direct sunlight. We used the nonparametric Kruskall-Wallis test to determine differences in the number of minutiae on degraded latent fingerprints, where differences were observed at the $\alpha = 0.05$ significance level. We chose the nonparametric test due to the non-normal distribution of the data.

To determine the error of the minutiae evaluation, we evaluated the fingerprints again independently of the previous evaluation by the same person. Differences in the number of minutiae on the latent traces after evaluation were minimal. We can conclude that the data were evaluated with minimal measurement error, which we verified using the technical measurement error (TEM = 0.98).

Results and discussion

After development and evaluation of latent fingerprints, we made a statistical analysis. Table 1 shows the descriptive statistics of the observed sample of degraded latent fingerprints due to light along with the characteristics of the environmental factor (direct sunlight) that influenced quality of latent fingerprints. Also included in Table 1 are the number of fingerprints left on the non-porous glass plates, the minimum and maximum number of minutiae, the average number of minutiae found on the degraded fingerprints, the average number of minutiae found on the degraded fingerprints as a percentage, the standard deviation, and the average value of the light intensity during which the latent fingerprints were exposed to direct sunlight.

The same number of latent traces were left on all glass plates (36). Subsequently, the average number of minutiae on the degraded latent traces, that were exposed to direct sunlight, was evaluated for a period of seven weeks (Table 1). The minimum number of minutiae (7) and the maximum number of minutiae (52) were evaluated. The average value of light intensity ranged from 7 471 to 7 586 LUX (value of light intensity).

Table 1: Descriptive statistics of evaluated degraded latent fingerprints exposed to direct sunlight

	N	Min	Max	$\bar{x}$	$\bar{x}$ (%)	SD	LUX
control sample	36	34	47	41.83	100.00 %	3.534	
one week	36	21	45	37.56	89.79 %	5.699	7 504
two weeks	36	21	52	44.92	107.39 %	6.720	7 471
three weeks	36	8	49	35.83	85.66 %	10.021	7 558
four weeks	36	7	50	40.19	91.08 %	9.001	7 550
five weeks	36	37	49	45.22	108.10 %	2.919	7 524
six weeks	36	22	48	42.39	101.34 %	5.719	7 538
seven weeks	36	26	47	40.89	97.75 %	4.809	7 586

N – number of fingerprints, Min – minimum number of minutiae, Max – maximum number of minutiae, $\bar{x}$ - average number of minutiae, $\bar{x}$ (%) – average number of minutiae in percentage, SD – standard deviation, LUX – average value of light intensity

We found 11.21 % decrease in the average number of minutiae after one week compared to the control sample. Two weeks after exposure of latent traces to direct sunlight, an increase of 7.39 % in the number of minutiae was evaluated in comparison to the control sample. Three weeks after exposure of latent fingerprints to direct sunlight, a 14.34 % decrease in the average number of minutiae was evaluated in comparison to the control sample. Further, a decrease of 8.92 % in the mean number of minutiae was evaluated after four weeks. At the fifth and sixth weeks, an increase in the mean number of minutiae of latent fingerprints exposed to direct sunlight was evaluated. An increase of 8.10 % in the average number of minutiae was evaluated at week five and 1.34 % at week six compared to the control. After the seventh week, from the exposure of the latent traces to this environmental factor, a decrease of 2.25 % in the average number of minutiae was evaluated in comparison to the control sample.

Descriptive statistics evaluated that in most cases there is no significant reduction in the average number of minutiae due to direct solar radiation in the individual observed time intervals. There is also no reduction in the quality of the visible latent fingerprints after their exposure to direct sunlight (Fig. 2).

The reason for the increased number of minutiae may be due to an error in the method of taking the evaluated fingerprints when the proband's fingerprints were taken at a different angle and a larger area of the distal phalanx was imprinted. Therefore, a larger number of minutiae was evaluated on the latent traces. A sample fingerprint was taken at an angle of 22°, which was also used to evaluate the minutiae that were present. An error in the method of taking latent traces was because some of the latent traces were left at a smaller angle and as a result a larger area of the finger was imprinted. De Alcaraz-Fossoul et al. (2016) in their study reported that at shorter time intervals, direct sunlight can have a positive effect on the quality of latent fingerprints. Only at longer time intervals (more than 24 weeks) of exposure of latent traces to direct sunlight they observed a decrease in the average number of minutiae. Based on these claims, we can assume that with prolonged exposure of latent fingerprints to direct sunlight, the latent fingerprints in our research would degrade according to the findings of De Alcaraz-Fossoul et al. (2016).

Compared to the study by Payne et al. (2014), we can conclude that our study did not evaluate such a significant degradation after seven weeks of exposure of latent fingerprints to direct sunlight. These differences may be caused by a different visualization method and a different surface on which the latent fingerprints were left.

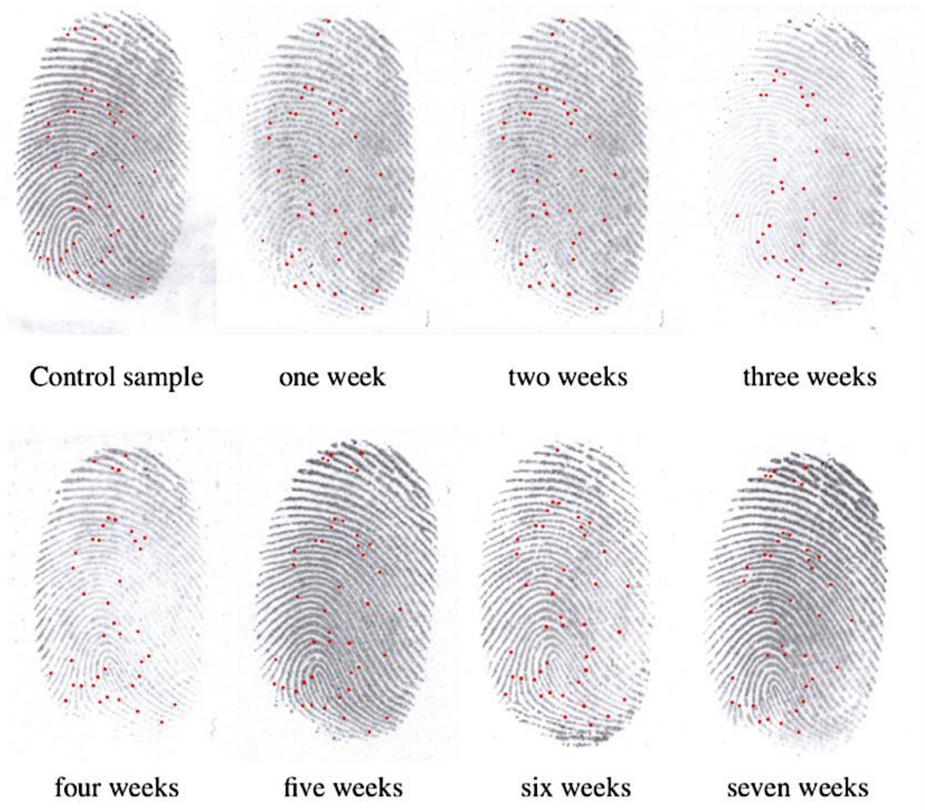

Fig. 2: Degraded latent fingerprints due to the direct sunlight exposure in different time intervals

Using the non-parametric Kruskall-Wallis test, it was evaluated that there were no significant differences in the average number of minutiae between the time intervals compared within the indicated time intervals: Control sample – four weeks, Control sample – six weeks, Control sample – seven weeks, one week – three weeks, two weeks – five weeks, three weeks – seven weeks, four weeks – six weeks, four weeks – seven weeks, six weeks – seven weeks. These differences were observed at the $\alpha = 0.05$ significance level. Differences in average number of minutiae between the time intervals compared were minimal. This may be because the light preserved the latent fingerprints and their substances. Based on the results, we can conclude that the influence of light had almost no effect on the quality of latent fingerprints (Table 2).

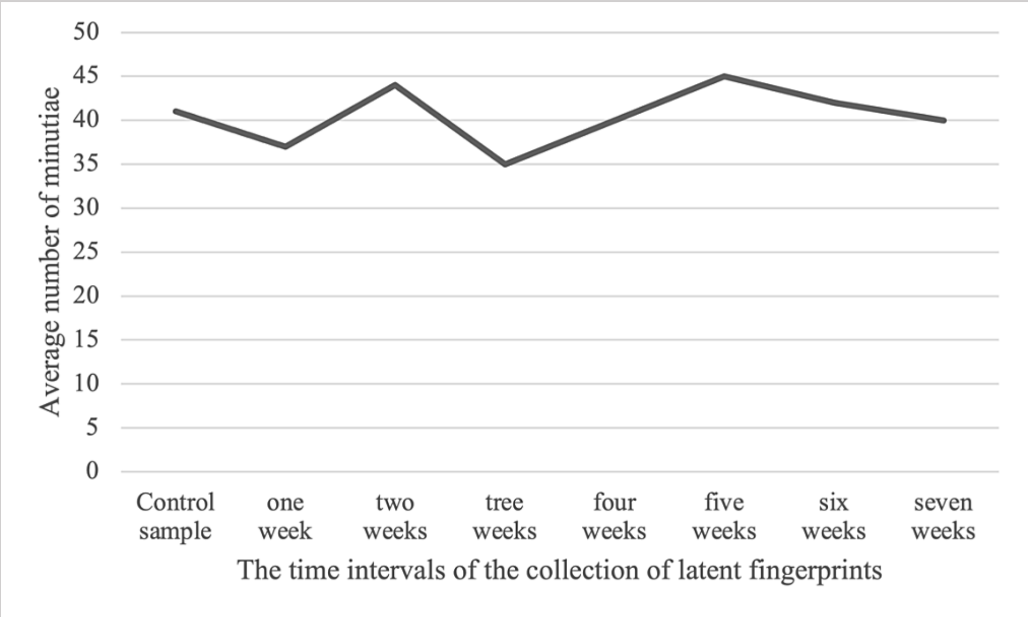

Fig. 3: Graphical representation of the average number of minutiae on degraded latent fingerprints due to direct sunlight at different time intervals

De Alcaraz-Fossoul et al. (2016) in their study reported that there is no significant degradation of latent traces due to direct sunlight in such a short time interval. These results can be confirmed in our study as well, as we can observe these minimal differences between the time intervals from the plot shown in Fig. 3. Therefore, we recommend to repeat this research and expose the latent fingerprints to the influence of direct sunlight for a longer period of time.

Significant differences in the average number of evaluated minutiae within compared time intervals were observed between the following intervals: Control sample – one week, Control sample – two weeks, Control sample – three weeks, Control sample – five weeks, one week – two weeks, one week – four weeks, one week – five weeks, one week – six weeks, one week – seven weeks, two weeks – three weeks, two weeks – four weeks, two weeks – six weeks, two weeks – seven weeks, three weeks – four weeks, three weeks – five weeks, three weeks – six weeks, four weeks – five weeks, five weeks – six weeks, five weeks – seven weeks. These differences may be caused by a mistake in the method of collecting evaluated fingerprints, where the fingerprints of the proband were collected at a different angle, resulting in a higher number of minutiae evaluated on the latent fingerprints. Direct sunlight did not have a significant effect on the latent fingerprints resulting in significant differences in the average number of minutiae between compared time intervals. The reason for these results may be that the light fixed the latent fingerprints and also the short exposure time of the latent fingerprints to direct sunlight. These differences can also be observed from the graph shown in Fig. 3. Differences in the average number of minutiae on degraded latent fingerprints could be minimal depending on time. On the basis of regular measurements of light intensity, we can conclude that the values during the seven weeks of research were on average approximately equal and the differences between them were minimal, and therefore we can consider this variable as a constant.

Table 2: Differences in the number of minutiae between the compared time intervals

Compared time intervals	**p – value**
Control sample – one week	**0.006**
Control sample – two weeks	**<0.001**
Control sample – three weeks	**0.014**
Control sample – four weeks	0.742
Control sample – five weeks	**<0.001**
Control sample – six weeks	0.208
Control sample – seven weeks	0.623
one week – two weeks	**<0.001**
one week – three weeks	0.750
one week – four weeks	**0.002**
one week – five weeks	**<0.001**
one week – six weeks	**<0.001**
one week – seven weeks	**0.023**
two weeks – three weeks	**<0.001**
two weeks – four weeks	**<0.001**
two weeks – five weeks	0.784
two weeks – six weeks	**0.011**
two weeks – seven weeks	**<0.001**
three weeks – four weeks	**<0.001**
three weeks – five weeks	**<0.001**
three weeks – six weeks	**<0.001**
three weeks – seven weeks	0.051
four weeks – five weeks	**<0.001**
four weeks – six weeks	0.353
four weeks – seven weeks	0.411
five weeks – six weeks	**0.024**
five weeks – seven weeks	**<0.001**
six weeks – seven weeks	0.080

Overall, our findings suggest that exposure to direct sunlight has minimal impact on the quality of latent fingerprints. Specifically, we observed no significant differences in the average number of minutiae between latent traces under different lighting conditions. These results provide new insights into the preservation of latent prints and have important implications for forensic investigations where lighting conditions may vary.

Conclusion

In this study, we evaluated 288 latent fingerprints that had been exposed to direct sunlight. We compared the average number of minutiae with the control sample. Within the descriptive statistics, we found that there was no significant reduction in the average number of minutiae on latent fingerprints that had been exposed to direct sunlight. We can also conclude that the quality of the latent fingerprints visualized after exposure to direct sunlight did not decrease over time. The analysis indicates only minimal differences in the average number of minutiae between the compared time intervals. This could be due to the fact that the light conditions did not have any significant impact on the latent fingerprints and the substances that compose them. Therefore, the findings suggest that the quality of latent fingerprints was hardly affected by the illuminance factor. In conclusion, the direct sunlight did not have a substantial effect on the overall quality of latent fingerprints. However, we can conclude that after a longer period of time from the exposure of latent fingerprints to direct light, the quality of the latent traces would decrease and the average number of minutiae would decrease proportionally with it. The differences in the average number of minutiae on latent traces exposed to direct sunlight may be due to errors in the method of taking the latent traces. An error in the method of taking latent traces was because some of the latent traces were left at a smaller angle and as a result a larger area of the finger was imprinted. Direct sunlight did not have a significant effect on the latent traces to produce noticeable differences in the average number of minutiae between the time intervals compared. This could be due to the fact that sunlight fixed the latent traces, and the exposure duration to direct sunlight was minimal. Therefore, it can be concluded that direct sunlight did not have a notable effect on the quality of latent traces, with any observed differences potentially being attributed to factors unrelated to light exposure. We can assume that with prolonged exposure of latent fingerprints to direct sunlight, the latent prints in this study would degrade whereby we can follow the study of De Alcaraz-Fossoul (2016). Therefore, we recommend repeating the research and exposing the latent fingerprints to direct sunlight for more than seven weeks.

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