POMORSKI UNIWERSYTET MEDYCZNY W SZCZECINIE

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ANALIZA WZORÓW OBRAŻEŃ U OSÓB ZMARŁYCH W DWÓCH NAZISTOWSKICH OBOZACH KONCENTRACYJNYCH Z CZASÓW II WOJNY ŚWIATOWEJ: KL STUTTHOF I KL TREBLINKA I

TRAUMA PATTERNS COMPARISONS OF PEOPLE WHO DIED IN TWO NAZI CONCENTRATION CAMPS: KL STUTTHOF AND KL TREBLINKA I

Rozprawa doktorska w dziedzinie nauk medycznych i nauk o zdrowiu

Dyscyplina nauki medyczne

Promotor: prof. dr hab. n. med. Mirosław Parafiniuk

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Table of Contents

List of abbreviations

PMI postmortem interval

BFT blunt force trauma

GST gunshot trauma

SFT sharp force trauma

HBL hat brim line

KL concentration camp

AL forced labor camp

DNA deoxyribonucleic acid

mtDNA mitochondrial DNA

STR short tandem repeat

SNP single-nucleotide polymorphism

XX female biological sex

XX? Possible female biological sex

XY male biological sex

XY? Possible male biological sex

N- number of cases

NA- not applicable

List of publications incorporated in thesis.

The doctoral dissertation is a series of three articles submitted for publication. On the day the thesis was submitted, one article got accepted for publication and two were still under the process of peer review. The doctoral candidate is the first author to all submitted papers.

1. **Drath J**, Machalski G, Holicki M, Dowejko J, Szargut M, Spradley K, Parafiniuk M, Ossowski A. ***Skeletal evidence of the ethnic cleansing actions in the Free City of Danzig (1939-1942) based on the KL Stutthof victims analysis.*** Science and Justice, DOI: https://doi.org/10.1016/j.scijus.2023.02.003.
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2. **Drath J**, Jarzęcka-Stąporek J, Lisman D, Szargut M, Jasiński ME, Spradley K, Parafiniuk M, Ossowski A. ***Slaughtered like animals. Revealing the atrocities committed by the Nazis on captives at KL Treblinka I by skeletal trauma analysis.*** Humanities & Social Sciences Communications, PENDING REVIEW.
   Impact Factor: 2.731
   Ministry points: 20
3. **Drath J**, Jarzęcka-Stąporek J, Zacharczuk J, Lisman D, Cytacka S, Szargut M, Bulut O, Spradley K, Jasiński ME, Parafiniuk M, Ossowski A. ***The Treblinka victims fought back. The analysis of the seven "Trawniki Men" buried in single graves in the former extermination and labor camp.*** Journal of Archaeological Science: Reports, PENDING REVIEW.
   Impact Factor: 0.73
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Moreover, the study results were presented during national and international meetings:

- ***What happened in KL Treblinka I? Unraveling World War II atrocities with the use of interdisciplinary forensic science methods.*** Oral presentation during 28th EAA Annual Meeting, Budapest, Hungary, 31 August- 3 September 2022.

- ***Wzory obrażeń okołośmiertnych u ofiar pochowanych w ukrytym grobie masowym na terenie byłego obozu koncentracyjnego z czasów drugiej wojny światowej, KL Treblinka I.*** Oral presentation during XLVIII Ogólnopolska Konferencja Naukowa Polskiego Towarzystwa Antropologicznego PTA, Łódź, 21-23 September 2022.
- ***Analiza obrażeń kranialnych okołośmiertnych ofiar obozu KL Stutthof (1939-1940).*** Poster presentation during 5th International Medical Student's Conference, Szczecin, 13-15 March 2020.
- ***Postmortem fate of KL Stutthof victims (1939-1940)- the human remains' burial and storage conditions influence on the trauma results analysis.*** Oral presentation during 26th EAA Virtual Annual Meeting, 24-30 August 2020.
- ***Cranial trauma analysis of the KL Stutthof victims (1939-1945).*** Oral presentation during FASE advanced course and one-day symposium, Brussels, Belgium, 12-14 September 2019.

The full information on publications and other scientific career achievements can be found under ORCID number 0000-0003-3528-3584.

Streszczenie.

Jednym z podstawowych zadań antropologa sądowego jest analiza obrażeń, szczególnie tych, które powstały okołośmiertnie. Dzięki wiedzy i umiejętnościom w rozróżnieniu normalnej budowy kości od kości patologicznej antropolog jest niezastąpiony w ocenie mechanizmu powstania obrażenia, czasu jego powstania, energii i siły zadającej uraz, sekwencji i ilości uderzeń oraz narzędzia, które przyczyniło się do powstania zmiany na kości. Te kompetencje są kluczowe w procesie określania przyczyny i okoliczności zgonu na materiale szkieletowym, co ostatecznie należy do obowiązków lekarza sądowego.

W czasie drugiej wojny światowej na terenach okupowanej Polski, Niemcy skonstruowali różnego rodzaju obozy, w których więzili, torturowali i zabijali ludzi. Jednak szczegółów tych mordów nie poznano do dziś. Poprzez współpracę Pomorskiego Uniwersytetu Medycznego w Szczecinie z Instytutem Pamięci Narodowej w latach 2018 i 2019 dokonano ekshumacji i analizy szczątków szkieletowych ofiar zamordowanych w obozie koncentracyjnym Stutthof i w obozie pracy Treblinka I.

Analiza obejmowała m.in. obrażenia powstałe okołośmiertnie, szczególnie te, które mogły bezpośrednio przyczynić się do zgonu ofiar. Szczątki kostne w obydwu przypadkach znajdowały się w stanie przemieszanym, ale pomimo tych trudności, udało się wykryć i przeanalizować wzory obrażeń powstałych na kościach. Celem pracy było wykazanie różnic i podobieństw we wzorach obrażeń okołośmiertnych zaobserwowanych na szczątkach szkieletowych ofiar obozu KL Stutthof i AL Treblinka I.

Wyniki badań ukazały, że zarówno na szkieletach z obozu Stutthof, jak i z obozu w Treblince przeważają obrażenia kości czaszek. U obydwu grup spotykane są obrażenia powstałe wskutek uderzeń narzędziem twardym i tępym, postrzału z broni palnej i uderzenia narzędziem ostrokrawędzistym, z ogromną przewagą uderzeń narzędziami twardymi i tępymi. Jednakże występują pewne różnice we wzorach obrażeń pomiędzy obiema badanymi grupami. W przypadku ofiar Stutthofu obrażenia najczęściej są typu liniowego i promienistego, z lokalizacją powyżej „linii ronda kapelusza”. Natomiast w przypadku ofiar Treblinki często spotykane były obrażenia depresyjne i koncentryczne z lokalizacją na tylnej części głowy (kość potyliczna lub tylna część kości ciemieniowych). Ponadto zaobserwowano różnice w ilości występowania obrażeń postkranialnych. Znacząco więcej obrażeń występuje u ofiar z obozu w Treblince niż w Stutthofie. U ofiar

Treblinki wykryto dodatkowo liczne złamania kości twarzoczaszki, takich jak szczęka, nos, okolice oczodołów, żuchwa, co było raczej niespotykane u ofiar Stutthofu.

Ukazane rezultaty przebadanych wzorów pozwoliły na wyciągnięcie wniosków na temat przypuszczalnej okoliczności śmierci ofiar. Prawdopodobnie ofiary obydwu obozów zmarły na skutek karygodnego działania osób trzecich. U ofiar obozu Stutthof brak złamań kości twarzoczaszki i nieliczne złamania kości postkranialnych może świadczyć o tym, że ofiary mogły być skrępowane w czasie egzekucji, lub też były nieświadome zbliżającej się śmierci i nie stawiały oporu napastnikom. Zaobserwowany typ obrażeń na kościach czaszek często jest spotykany w momencie uderzenia w głowę niepodpartą, swobodną do poruszania się.

Natomiast u ofiar obozu Treblinka I zauważono liczne złamania kości twarzoczaszki i kości postkranialnych, szczególnie tych, które budują obręcz barkową i rękę. Może to oznaczać, że ofiary stawiały opór agresorom i próbowały się bronić przed uderzeniami napastników. Na kościach czaszek pojawia się typ obrażeń koncentrycznych i depresyjnych, co często jest spotykane u ofiar uderzeń narzędziem twardym i tępym o dość małej powierzchni (np. młotek lub pałka) w głowę podpartą na twardym podłożu (np. na pieńku lub kamieniu).

Różnorodność typów obrażeń, jak i lokalizacji miejsc uderzeń, u ofiar obydwu obozów pozwala wnioskować, że do zabicia więźniów przyczyniło się wielu napastników.

Zademonstrowane wyniki badań udowodniły wartość analiz wzorów obrażeń w procesie oszacowania przyczyny i okoliczności śmierci ofiar w stanie zeszkieletowanym. Badania można w przyszłości rozszerzyć o szczegółową analizę fraktograficzną zaobserwowanych złamań.

Abstract.

One of the primary tasks of a forensic anthropologist is trauma analysis, especially those that occur perimortem. Thanks to knowledge and skills in distinguishing a normal bone structure from a pathological one, the anthropologist is irreplaceable in assessing the mechanism of trauma, time of its occurrence, energy and force inflicting the trauma, sequence and number of blows, and the tool that contributed to the formation of the bone lesion. These competences are crucial in the process of determining the cause and circumstances of death in skeletal material, which is ultimately the responsibility of the medical examiner.

During the Second World War in occupied Poland, the Germans constructed various types of camps where they imprisoned, tortured and killed people. However, the details of these murders have not been revealed to this day. Through the cooperation of the Pomeranian Medical University in Szczecin with the Institute of National Remembrance, in 2018 and 2019, the exhumation and analysis of the skeletal remains of the victims murdered in the Stutthof concentration camp and in the Treblinka I labor camp were carried out.

The analysis included perimortem trauma assessments, especially ones that may have directly contributed to the victims' deaths. The skeletal remains in both cases were in a commingled state, but despite these difficulties, it was possible to detect and analyze the patterns of trauma on the bones. The aim of the study was to demonstrate the differences and similarities in the patterns of perimortem injuries observed on the skeletal remains of the victims of KL Stutthof and AL Treblinka I camps.

The results of the research showed that, equally, the skeletons from the Stutthof camp and the Treblinka camp suffered from injuries to the skull bones. In both groups there are fractures resulting from blows with a hard and blunt instrument, shots from a firearm and blows with a sharp-edged tool, with a huge predominance of blows with hard and blunt tools. However, there are some differences in trauma patterns between the two study groups. In the case of Stutthof victims, fractures are most often of the linear and radiating type, located above the "Hat Brim Line". Whereas, in the case of Treblinka victims, depressive and concentric fractures were common, localized on the back of the head (occipital bone or the posterior side of the parietal bones). In addition, differences in the incidence of post-cranial trauma were observed. Significantly more injuries occur in the

victims of the Treblinka camp than in Stutthof. Within the victims of Treblinka, additionally were detected numerous fractures of the craniofacial bones, such as the maxilla, nose, orbital edge, and mandible, which were rather absent in the victims of Stutthof.

The presented results of the examined trauma patterns allowed me to draw conclusions about the presumed circumstances of the victims' deaths. It is probable that the victims of both camps died as a result of the reprehensible actions of third parties. In the victims of the Stutthof camp, the lack of fractures of the craniofacial bones and a few fractures of the postcranial bones may indicate that the victims could have been restrained during the execution, or were unaware of their approaching death and did not resist the attackers. The observed type of injury to the skull bones is often encountered when the head is hit unsupported and free to move.

In contrast, in the victims of the Treblinka I camp, numerous fractures of the craniofacial and postcranial bones were noted, especially those that built the shoulder girdle and hand. This may mean that the victims resisted the aggressors and tried to defend themselves against the attackers' strikes. Concentric and depressive injuries appear on the skull bones, which are often seen in victims of blows with a hard and blunt object of a fairly small area (e.g. a hammer or a club) on the head supported on a hard surface (e.g. on a stump or stone).

The variety of trauma types and places of impacts on victims from both studied samples, allows us to suspect that multiple assailants contributed to the victims' demise.

The demonstrated study results demonstrated the value of trauma pattern analysis in the process of estimating the cause and circumstances of death from skeletonized remains. The research can be extended in the future with a detailed fractographic analysis of the observed fractures.

1. Introduction.

The human bone is built of organic and inorganic components, which makes the bone a material elastic and enduring at the same time [1]. It is an anisotropic material, which means that it has different properties in different directions. When a force is applied to a bone, trauma may result. The relationship of stress and strain on bone deformation is described by Young's modulus [2]. When the applied force is lower than the yield point, the bone will react in elastic deformation. That state can be reversed when the force is no longer applied. With increased force, the bone crosses the yield point and plastic deformation takes place. Finally, after increasing load, a failure is reached and bone fracture occurs [3], [4].

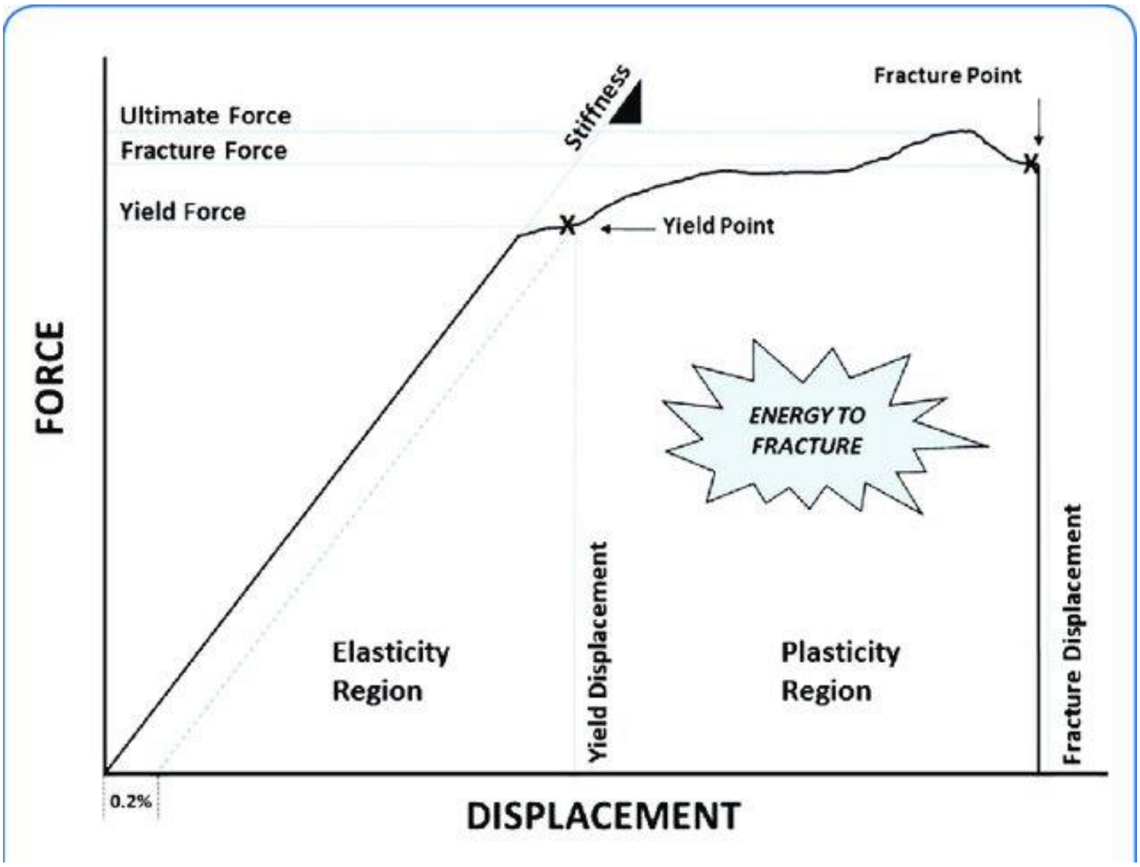

Figure 1. Young's modulus of stress-strain on bone deformation and fracture. Adapted from Hart, 2017.[5]

Depending on intrinsic and extrinsic factors, bone reaction to force may result in various mechanisms. Intrinsic factors include bone geometry and composition, which vary between populations, sexes, biological ages. Certain pathological conditions also influence bone strength [3]. Extrinsic factors include the impacting object, load weight and velocity [6]. We distinguish several main forces that act on the skeleton: compression, tension, bending, shearing and torsion. The strength of bones depends on the direction of force. Bone is more resistant to compression than tension [7]. The bone's compressive strength is proportional to its density [6]. And these forces can cause fracture type transverse, oblique, displaced, non-displaced, complete, incomplete, greenstick or comminuted. The trauma mechanism is usually described as an effect of blunt force, sharp force and gunshot or projectile force.

Bone trauma can occur at different times of an individual's life. When referring to the time of trauma occurrence, a forensic anthropologist uses the terminology antemortem, perimortem and postmortem. However, the word "perimortem" has a different meaning in anthropology than in medicine [8]. For anthropologists, a perimortem trauma is a trauma to a fresh, hydrated bone. That means that the fracture could occur sometime after the death event, when the bone was still in a hydrated state.

For the past forty years, the role of forensic anthropologist has become more significant, and nowadays it exceeds the mere biological profile assessment [9]. Today, a forensic anthropologist is routinely asked to perform trauma analysis and interpretation and actively assist a forensic pathologist with cause and manner of death determination. Extremely important is the ability to correctly interpret the pattern of perimortem fractures on the studied skeleton. Forensic anthropologists are able to recognize the pattern of skeletal injuries in a much better way than medical practitioners. Knowing the bone characteristics, the anthropologist can recognize whether a plastic or elastic deformation took place in a bone, and because of that, whether the trauma was caused by a blunt force or a gunshot [6], [10]. Moreover, anthropologists can locate the point of trauma origin, fracture propagation, number and sequence of impacts, the amount of force and class of a weapon used. However, the extent of information the researcher can read from the skeleton depends greatly on its preservation state [11]. Therefore, should be included routinely in each expert opinion the state of preservation and the inventory of the recovered skeletal elements.

The analysis of the fracture features and its distribution pattern on the skeleton can be helpful in the reconstruction of the circumstances of death. For example, the fractures observed on ribs in a result of fall from a height differ from the result of a violent encounter [6]. By analyzing cranial fracture patterns, we gain information on the impact location, the object and its surface area. Commonly, the cranial fractures are described as linear, complex and comminuted. Recently, forensic skeletal trauma analysis has changed from morphological and typological description to interpretation based on bone mechanics, especially its reaction to force and load. Science that deals with that approach in forensic skeletal fracture study is called fractography [12].

By setting the obtained results of a trauma pattern within the crime context, we gain complete information on the event of death. The significance of trauma pattern analysis in forensic situations has been shown in various scientific publications. For example, Love describes a cranial fracture pattern in a victim that was hit multiple times with a hammer [13]. Ta'ala [14]showed that the cranial pattern on the skulls from the Khmer Rouge collection corresponds with the written historical sources on the method of killing the executioners in Cambodia- that is on hitting the kneeling prisoner on the back of the head with a blunt object [15]. Bird (2013, [16]) studied trauma patterns in victims of the Soviet regime in Lithuania. She found that at the beginning of the aggressor's occupation, firearm trauma was prevalent, and later blunt force trauma became the more frequent method of execution.

There is an abundant amount of information about the horrors of the Second World War. We know that millions of people were killed in various types of camps created by the Nazis, mainly on Polish land [17], [18]. However, nobody has ever studied patterns of skeletal trauma on people killed in those camps. Here, I present the study result of perimortem cranial trauma pattern comparison of people killed in two German Nazi camps. The work is divided into three separate papers that were submitted for publication in non-predatory peer-reviewed journals.

1.1. Publication 1. ***Skeletal evidence of the ethnic cleansing actions in the Free City of Danzig (1939-1942) based on the KL Stutthof victims analysis.***

The first published paper tells the story of the KL Stutthof victims. They were the Polish elites from the Free City of Danzig who fell casualties during the ethnic cleansing actions in Danzig between 1939 and 1942 [19]. They were interned in Stutthof concentration camp, and a few weeks later they were brought to the woods and murdered. Their corpses were buried in a mass burial pit in the woods [20].

The exhumation and initial identification of the victims ensued in two stages, in 1946 and in 1979. The remains that were not identified then were placed altogether in two sarcophagus and put in a crypt under a monument (fig 1-3 in this chapter). In 2018, the sarcophagus containing the remains was transported to the Forensic Genetics Department in Szczecin for anthropological and genetic analysis. The estimated minimum number of individuals was thirty-four.

Figure 1. Two sarcophaguses under the monument in the Stutthof Museum

Figure 2. Memorial plague with names of supposed victims laid in sarcophagus under the Stutthof Museum monument.

Figure 3. The commingled remains in sarcophagus.

In the course of the study, perimortem trauma was noticed on the skulls of eighteen people and three humeral bones. The majority of the trauma mechanism was blunt force trauma, followed by gunshot trauma and sharp force trauma. The observed trauma pattern in blunt force injuries shows that the majority of cranial fractures were located above the Hat Brim Line, which in medico-legal studies is usually linked to interpersonal violence. The fracture types are usually linear and radiating.

The gunshot trauma was caused by a probable 9mm bullet caliber. The entry hole is usually located on the occipital bone and the exit is in the front of the head. That pattern is typical for executions. Sharp force trauma marks were visible only on one skull that was not preserved very well. It is impossible to say what kind of weapon caused the injury, nor what was the exact time of the trauma occurrence (whether the trauma was a cause of death or it happened postmortem).

On several crania multiple impact points were observed, and on one cranium a combination of blunt force trauma and a gunshot trauma to the top of the head was noticed.

In postcranial bones, the perimortem fractures were only observed in arm bones. No fractures of forearm bones and hand bones were visible. Moreover, no mandible fractures were detected. Based on the varied killing methods, it is suspected that multiple assailants were involved in the execution process.

1.2. Publication 2. ***Slaughtered like animals. Revealing the atrocities committed by the Nazis on captives at KL Treblinka I by skeletal trauma analysis.***

The second paper enlisted in this project concerns the analysis of commingled skeletal remains exhumed from a clandestine mass burial pit in the Execution Site of near the former Treblinka forced labor camp. In that place were buried people brought for execution from Pawiak prison in Warsaw, Jewish ghetto, people too weak to work in the labor camp, people sentenced to death for disobeying the camp rules and Jewish and Roma families brought here from other countries, such as Hungary, Italy etc [21], [22]. After the German evacuation from the camp, no traces of graves, nor camp buildings were left. The initial investigation took place several weeks after the Nazis left [23]. Then it was revealed that on that site there were many mass graves. However, from that time until 2019, no physical exhumation of the bodies buried in those graves took place. Some people even began to deny the existence of those graves [24].

In 2019, when the plan to modernize the bus parking lot was in the process of implementation, the archaeological survey in the parking place was executed. During the survey, a previously unknown mass burial pit was uncovered. In the pit were the commingled remains of forty-nine people. The remains after the exhumation were transported to the Forensic Genetics Department in Szczecin for anthropological and genetic studies.

The perimortem trauma was observed on cranial and postcranial elements, but cranial trauma was prevalent. It was observed on thirty-four studied skulls. The second element which showed a high amount of perimortem trauma is mandible. It was shown on fifteen bones. The vast majority of the trauma mechanism was blunt force trauma. The trauma type varied, depending on the impact location. In several cases, depressed concentric fractures were visible. That kind of trauma is usually observed after hitting a head that is supported on a flat surface with a blunt instrument such as a hammer. Those results were confirmed by the published Treblinka survivors' testimonies, which state that the Nazis put the captives' head on a wooden log and hit it with a mallet.

Apart from blunt force trauma, gunshot injuries caused by a small bullet caliber were noticed on the skulls. The entry hole diameter measures around 7mm. The entry wound was located on the occipital bone, or the posterior part of the parietal bone, and the exit on the frontal bone. However, the number of skulls with gunshot injuries was much smaller than the number of skulls with blunt force trauma. On several skulls, sharp force trauma was detected (fig. 4-5 in this chapter). Because the mastoid processes remained intact, it has been inferred that the tool must have been long and narrow.

Figure 4. Sharp force trauma on occipital condyles of skull nr TI_1082.

Figure 5. Sharp force trauma on the C2 dens.

Among the postcranial elements, there are fractures of the ulna and metacarpals. The hand bones' fractures could be a sign of the victims fighting back with the attacker. Ulna fractures, on the other hand, could result from protecting the body against the attack, so called "parry fractures".

The variety of the observed trauma pattern lets us infer that there were multiple assailants and possibly the murders took place at various locations in the camp. The postcranial trauma pattern suggests that the victims were brutally beaten around the time of their death.

1.3. Publication 3. ***The Treblinka victims fought back. The analysis of the seven "Trawniki Men" buried in single graves in the former extermination and labor camp.***

The third article submitted for publication tells the story of another group of people that died as well in Treblinka, the guardians (SS-Wachmannschaften). They were men selected from Ukrainians, Lithuanians, Russians and other nationals to help German Nazis in terrorizing and controlling the oppressed groups [25]. They played a very important role in the implementation of The Reinhard Action [26]. Because they were obligated to pass the training in Trawniki camp, they were called "Trawniki Men" or the "Blacks" from the color of their uniforms. Very little is known about their life and death in the camps where they served.

During an archaeological survey in 2019, a couple of meters from the main road, a row of individual burials was revealed. Seven of those burials were explored, each containing one body. The bodies were interred in coffins, with funeral wreaths placed on top of the coffin. Personal goods were buried together with the corpses. The analysis of the artefacts showed that the bodies were wearing German uniforms. Based on those artefacts and the unusual manner of interment in Treblinka, the researchers came to the conclusion that the graves belong to the Treblinka guards.

The exhumed skeletal remains were transported to Pomeranian Medical University for detailed anthropological and genetic analysis. The assessed biological profile shows that the skeletons belong to males, aged from below 25 to over 40 at the time of death. In two skeletons, perimortem trauma was found. One of them manifested multiple gunshot trauma to the head. Based on the bullet trajectories, the pattern of fractures on the skull, it can be inferred that the magnitude of the shot was relatively low. There is no exit wound, one of the bullets stayed imbedded in the cranial base bone. It is quite possible, that the bullet or the weapon was self-made in an amateur manner. The other skeleton had one gunshot trauma to the knee, with the bullet imbedded in the kneecap, and possible blunt force trauma to the skull.

The analysis of the trauma pattern of those two skeletons allowed the researchers to form a hypothesis, that the trauma could occur during one of the prisoners' rebellion, perhaps even the famous Treblinka uprising in August 1943.

The preservation state of all seven skeletons was poor. The best preserved was skeleton number 2, with gunshot trauma. Thanks to the good preservation state of his skull, it was possible to perform facial approximation of his skull. That could even help in the personal identification process.

2. Research hypotheses

1. All victims from both camps manifested the same perimortem trauma pattern, which suggest imposed from the top strict directions on performing the executions.
2. All the victims knew that they were going to die and they did not oppose the execution process (no defensive fractures detected).
3. Trauma pattern analysis proves to be crucial in inferring the cause of death from skeletal remains.

3. The research aim.

The main goal of the research was to analyze and interpret perimortem trauma pattern visible on skeletal material of people who died in two German Nazi camps: KL Stutthof and KL Treblinka I.

4. Skeletal evidence of the ethnic cleansing actions in the Free City of Danzig (1939-1942) based on the KL Stutthof victims analysis.

4.1. Abstract:

In the early days of World War II, many of the prominent and influential people of Polish nationality from the Free City of Danzig were arrested by the Germans and sent to the nearby concentration camp KL Stutthof. Nearly a hundred of them died within the next seven months upon their arrival, and were buried in a clandestine mass grave in a nearby forest. However, the exact nature of their death is unknown, as it is unclear what the attitude of the aggressors was toward the victims. We do not know whether there was only one executioner or there were several assassins, nor if the killing methodology was consistent with the other state-regulated executions.

The studied material represents the commingled remains of a minimum thirty-four people, possibly all male, aged from under eighteen to over sixty at the time of death. Perimortem traumatic lesions are shown mainly on the skull bones. We asked whether the perimortem trauma lesions visible on the victims' skeletons could be informative on the cause and manner of their death.

Our results show the prevalence of the perimortem trauma inflicted by a blunt object are on the parietal bones above the Hat Brim Line (HBL), which is commonly associated with a violent attack. The gunshot trauma was usually localized on the occipital bone or posterior parietal, which could indicate a shot to the back of the head, and this was commonly encountered during executions. No signs of defensive injuries can be explained either by restraining of the hands or by a surprise attack. The abundance and variability of the trauma type can be evident of multiple assailants. Moreover, the multiple impact points detected on several crania prove unnecessary overkill and brutality, which reflects the personal attitudes of the executioners towards the victims.

4.2. Introduction:

Throughout human history there have been many instances of crimes against civil populations [17]. From the legal perspective, the search and prosecution of those crimes began after the Hague Conventions in the early twentieth century and later during the Leipzig War Crime Trials and Nuremberg and Tokyo Trials [27]. According to the United

Nations Organization, ethnic cleansing has not been acknowledged as an independent crime under international law, and does not have a proper definition. However, the United Nations Commission of Experts in their report on Yugoslavia's crimes describe ethnic cleansing as "…a purposeful policy designed by one ethnic or religious group to remove by violent and terror-inspiring means the civilian population of another ethnic or religious group from certain geographic areas"[28]. These actions constitute crimes against humanity and can be prosecuted by laws of the Genocide Convention [29].

When Hitler invaded Poland on September 1st 1939 his main goal, apart from assimilation of Polish territory, was a complete eradication of the Polish nation [19], [30]. As a consequence, many civilians died as casualties of war. In order to implement the nation eradication plan, the invaders began with the liquidation of the Polish intelligentsia, the elites, that would incapacitate the rest of the people and prevent any resistance against the aggressors [31]. The hostile tendencies of Nazi Germany towards Polish leaders were visible in the Free City of Danzig even before the outbreak of the Second World War and resulted in the creation of Stutthof concentration camp [19], [32], [33].

The first arrests and deportations to the nearby concentration camp KL Stutthof began as soon as September 2nd 1939, even though Polish defenders fighting in the Westerplatte peninsula were yet to surrender [34]. The first transportation of 150 people to KL Stutthof included, among others, members of the clergy, teachers, political leaders and clerks. Most of them were killed within months of their arrival [19] [35].

The exact methods of the executions that were implemented by the Nazis remain unknown. The survivors testified that they heard shots coming from the woods, but the details of what exactly happened to the arrested intelligentsia remain mystery. It is unclear whether the shots were the main method of killing or only a supplementary method to finish the ones that did not die immediately after a blow with a blunt instrument or a sharp weapon.

Forensic anthropology played a very important role in cases of human rights violations both in historical and forensic context. The field's contribution is especially evident in cases of personal identification of US soldiers that died during World War II [36]. Another example are the results of search, recovery and analysis that lead to identification of the Second World War heroes of different nationalities that died across the present country's borders [37]. In more recent cases of human rights violations, forensic anthropologists contribute in the same manner as when working with WWII remains, by establishing the biological profile of the victim and by performing trauma assessment [38]–[40]. With emerging DNA technologies in personal identification process, even on highly degraded material, the forensic anthropology methods has fallen into secondary methods of identification [41] (Interpol DVI guidelines). However, the anthropological involvement in skeletal pathology diagnosis and trauma pattern interpretation remains very strong and forensic anthropologist's expertise is a valid asset in the process of cause and manner of death determination [9], [42]. Regarding the Stutthof case, the interdisciplinary team was involved in the personal identification process (forensic anthropologists, forensic geneticist and forensic pathologists).

The objective of the study was to describe and interpret the perimortem trauma pattern visible on the remains of the exhumed victims that would be relevant in the reconstruction of the circumstances of death [43]. The pattern will show the relationship between the attacker and the victim, and possibly will provide the answer to whether the victims fought back before the death or were taken by surprise and did not fight back. The trauma type and analysis of the weaponry used in the killing will help in the determination of the cause and manner of death.

4.3. Material and methods:

4.3.1. Material:

The first executions of the KL Stutthof prisoners started on January 11th 1940 and took the lives of twenty- two people. All of them were buried in a clandestine pit that served the purpose of a concealed mass burial. The second part of the execution was carried out the day before Easter, on March 22nd 1940; 67 people lost their lives then. Among the dead were religious leaders and many highly educated people from the Danzig area. Their bodies were also interred in a concealed mass burial [32]. The bigger mass grave, that comprised 67 bodies, was exhumed just after the war in 1946. The majority of those victims were identified and buried in the cemetery. The smaller grave was not exhumed until 1979, because of the environmental conditions that prevented the exhumation. The area was flooded seasonally and after several years it became a marsh. Only in the late seventies of the twentieth century did the conditions improve enough to permit digging. By the initiative of Andrzej Chudy, in collaboration with the Stutthof Museum, the search of the victims' bodies took place in the forest near the former KL Stutthof camp. As a result of the exploration, in the Stegna Forest District, a mass grave was found next to the grave exhumed in 1946. The grave contained the bodies of the missing Polish citizens killed in January 1940 [20]. Then the District Commission for the Investigation of Nazi Crimes in Danzig carried out the exhumation process and investigation and announced in Dziennik Bałtycki the names of 16 people that were shot by the Germans in January 11th 1940 [44].

Some of the victims were identified on the basis of the artefacts that were found on the remains. The skeletons of the people who were not identified, were commingled and put together in two huge sarcophaguses (fig. 1, 2 in the supplement) that were placed under a monument in Stutthof museum [19].

In 2018, by the command of the National Institute of Remembrance (NIR) prosecutor, the remains from two sarcophaguses were exhumed by DNA analysts, and sent to the Pomeranian Medical University in Szczecin for anthropological, medical and genetic analysis that would lead to personal identification. The commingling (fig. 3) caused the loss of information on individual skeletons, and as a result some of the victims may never be identified. It was impossible to assign each skeletal element to a single individual in the given time period allowed for the analysis by the NIR prosecutors. Therefore, the best approach to take was to establish the minimum number of individuals [45] and to analyze all skeletal elements separately, by type. In total, the anthropological analysis was performed on over a thousand skeletal elements. The skulls and long bones consisted of over 400 elements, by adding other skeletal parts (ribs, hand bones, feet bones, vertebra, clavicles, scapulas, sacrum), the total number rises to over a thousand.

4.3.2. Methods:

a. Preservation state:

In the postcranial elements the overall preservation state is good, most of the long bones preserved their structure. The predominant color is brown, dark brown and blackish. Several bones manifest lighter coloration, dark yellow and light brown. Bone number G.3 (femur) was of color gray-white with greenish discoloration. Bone number G.35 was of green color. The bone texture preservation varied, the majority of bones show signs of erosion in the form of chipping and flaking of the bone periosteum. Some elements were preserved without significant surface changes (e.g. G.7, G.8, G.31, G.32, G.17, G.18). The structure of most bones is intact, a few elements show bone loss in the proximal and distal epiphyseal area. On some elements, there are visible traces of cuts on the bones (femurs and hip bones). Those could be the results of an autopsy that were performed just after the exhumation, or it could be the effect of postmortem analysis with a use of invasive methodology. On many bones were preserved remnants of soft tissues and lipids. Some bodies did not reach skeletonization stage, but retained their decomposition on saponification stadium.

In the case of the skulls, the preservation state also varies, but they all wear taphonomic alterations that are typical for underground body decomposition. The bone color is yellowish and brown. On most of the skulls there are visible signs of erosion on the bone surface in the form of flaking and chipping of the periosteum. Only eight skulls were preserved without visible significant structural damage, other skulls were in a very fragmented state, some with a perimortem trauma signs. Inside those skulls were found traces of faunal activity in the form of nests inside the cranial vaults (birds or rodents). Inside the skulls numbered G.224 was a dried bat carcass. Some skulls had preserved fossilized or mummified remnants of brain tissue.

On almost all of the skulls and many long bones there is visible high flora activity, there are roots grown into the bones, etched in the skulls. The roots are rather thick and long. The total taphonomic alterations are typical for a mass grave decomposition process. The bodies that retained soft tissues and were not skeletonized, were probably laid in the center of the grave. Whereas the skeletal elements that were poorly preserved, with roots etched and dark color were located near the surface, in the proximity of the plant roots. The bone number G.3, that was very light in color, could have been exposed on the ground surface and bleached with the UV light. The green discoloration were the remnants of algae, which could indicate a humid environment of the bone surroundings. The described postmortem changes are consistent with the historical sources on the exhumation process and postmortem examination that took place in 1979. As the skeletal remains were later put in two sarcophaguses, the rodents had access to them, thus the nests' remnants in the skulls. Based on the taphonomic alterations as well as historical sources we must assume that all the remains belong to people who died at the same time frame, in 1940.

b. Biological profile:

Bones were marked with ordinal numbers for descriptive purposes of individual skeletal elements (G.1-G.410). The biological profile components were assessed for each of the skeletal components separately. Age-at-death was estimated from the stage of the union of the long bones' epiphysis [46], the pubic symphysis morphology [47], the auricular surface morphology [48] and, in the case of skulls, the obliteration of cranial sutures [49]. The biological sex was estimated with a use of metric and non-metric methodology from the coxal bones [50], [51], from femoral bones [52], [53], and from the skulls [54]. Ancestry was assessed from the skulls with the use of a metric method software, Ancestrees [55] and a non-metric traits method [56]. Stature was estimated with the use of the femoral bone measurements and equation with regard to the assessed biological sex [57]. All the measurements and metric data analysis were carried out by one person, a forensic anthropologist, as this was the only qualified person employed in the Forensic Medicine Faculty of Pomeranian Medical University.

c. *Trauma analysis:*

Trauma was evaluated by the estimated time of occurrence (perimortem, antemortem or postmortem) using the anthropological meaning of the word perimortem (that is trauma that happened on fresh, hydrated bone) [58]. From the whole assemblage the elements that manifested perimortem trauma lesions were selected for the analysis. As the majority of traumatic lesions were located on skulls, the rest of the analysis was performed on those skeletal elements. Furthermore, cranial traumas are far more lethal than other skeletal fractures. Each traumatic lesion was described with information on the type of the lesion and location on the skeletal element. When possible, the injuries were measured with a spreading caliber, and the results were noted in millimeters. In order to confirm or reject the traumatic lesion assessment, we performed a CT scan of crania on a medical scanner (fig. 10), Somatom Definition AS, with settings recommended for dry bone scanning [59], that is kV= 120, mAs= 370. For radiological analysis, a software, syngo.via was applied. The objects were scanned through layers 0,75 mm thick and 3D reconstruction was made in the window “Bone” (fig. 10). The scanning images were studied by three specialists altogether: an anthropologist, a medical pathologist and a medical radiologist. In cases of discrepancies in the results provided by macroscopical analysis and radiological analysis (e.g. the disagreements on trauma presence or absence) the results of the CT scans were considered to be more reliable.

Because of the small research sample, we chose to apply empirical research and descriptive study rather than statistical analysis. We estimated a trauma frequency indicator based on the number of preserved cranial elements and the number of trauma impacts. That indicator was later used when creating figure 4 and figure 6.

d. *Genetic analysis:*

For the purposes of the genetic study, petrous parts of temporal bones from 22 skulls were prepared. The bone material was cleaned mechanically with a precision drill and chemically with the use of 0.5% Tween 20 (Sigma-Aldrich), and finally ground in a liquid nitrogen environment. DNA was extracted from 25 mg of bone powder using the PrepFiler ™ BTA Forensic DNA Extraction Kit Thermo Fisher Scientific, TFS, according to the manufacturer's instructions, and eluted in 50 µl of elution buffer. The Quantifiler ™ Human DNA Quantification Kit (TFS), which incorporates the Real-Time PCR method (RT-PCR) was used to evaluate the quantity and quality of the DNA. According to the manufacturer's instructions and an internal validation study, the presence of PCR inhibitors in the extract was confirmed when IPC C_t for a given sample was 31 or higher. As part of the personal identification process, extracts were subjected to multiplex amplification reactions using the GlobalFiler ™ and Yfiler™ Plus PCR Amplification Kit (both: TFS), to obtain STR profiles of the victims. Separation of the amplification products was obtained using a 3500 Series Genetic Analyzer (TFS) as per user manual. The results were analyzed using the GeneMapper® ID-X Software v1.6 (TFS) software. For the purpose of the determination of genetic sex, a multi-marker approach was applied with the use of two aforementioned STR typing kits. The Global FIler™ kit allows for simultaneous allele calling within, apart from 21 autosomal STR markers, 1 Y-STR marker (DYS 391), an insertion/deletion marker on the Y chromosome (Y indel), and a fragment of the Amelogenin gene. The Yfiler Plus™ kit allows for simultaneous amplification of 27 Y-STR markers (DYS438, DYS627, DYS458, DYS437, DYS391, DYS392, DYS635- Y GATA C4, DYS19, DYS390, DYS439, DYS456, DYS393, DYS449, DYS387S1 a⁄b, DYS576, DYS460, DYS533, DYS389 I⁄II, DYS570, DYS385 a⁄b, DYS481, YGATA H4, DYS518, DYS448). Based on all available markers for genetic sex determination, we have assigned appropriate genetic sex categories: victims were assigned either "XX" for lack of markers of the Y chromosome when autosomal markers were present, or "XY" when the presence of Y-chromosomal markers was detected. If a genetic profile would show signs of contamination, it would have been rejected from analysis.

Mitochondrial DNA hypervariable fragments I (HVI) and II (HVII) were amplified using the HotStarTaq Master Mix Kit (Qiagen) and two pairs of primers described by Nilsson et al. [60] (HVI: IFb-16128, IR-16348; HVII: IIFa-45, IIR-287). Amplification products were subjected to enzymatic purification using FastAP Thermosensitive Alkaline Phosphatase (TFS) and Exonuclease I (TFS), followed by cycle sequencing using BigDye™ Terminator v3.1 Cycle Sequencing Kit (TFS) and respectful sequencing primers. Reaction terminators were removed from sequencing products with the ExTerminator kit (A&A Biotechnology). Product detection was performed on a 3500 Genetic Analyzer sequencer. Sequencing results were analyzed using Sequencing Analysis Software 7 (TFS). Consensus sequences were created and compared to the revised Cambridge Reference Sequence with Sequencher 5.4.6 (Gene Codes). Individual electropherograms were visually assessed in terms of them being single-source, and consensus sequences were created only if all sequences of specific ranges showed concordant mutations. The sequences were then compared to the database of haplotypes of all persons involved in the study and only when no match was detected the mitotypes were further used for haplogroup estimation using the EMPOP database [61] and the HaploGrep software [62]. When both tools gave consistent results, haplogroup estimations were accepted. Since the estimation was based on a restricted fragment of the mitogenome (HV1 and HV2), when no specific haplogroup could have been assigned, the superior haplogroup was noted. Thus in this context R0 haplogroup means "all haplogroups descending from R0", not R0*.

For each step of genetic analyses (DNA isolation, quantification, amplification, capillary electrophoresis, mitochondrial DNA testing), negative and positive controls were created with the use of PCR grade water or synthetic DNA of a known profile, respectively. The testing results were analyzed only if negative controls showed no result and positive controls showed correct profiles.

As the majority of results of genetic testing lay out of the scope of this paper, we present only subject-relevant genetic results that would complement anthropological analyses: the determination of genetic sex of the victims – based on STR testing with the two kits mentioned before, and biogeographic ancestry analysis based on mitochondrial DNA haplogroup estimation, as well as general sample parameters to give an overall picture of the challenges of DNA testing in low-template material.

4.4. Results:

4.4.1. Minimum Number of Individuals:

The material consists of over 400 commingled skeletal elements from minimum thirty- four people (see appendix 1). The skeletal elements from the lower extremities prevail over the upper ones. The highest number of bones that were the basis of the minimum number of individuals estimation was the left femoral bone and the skulls (34 elements).

As the studied material was highly fragmented, many fragments were not assigned to any of the skulls. Only eight of thirty- four skulls were preserved without any structural damage; the rest of the material had significant preservation deficiencies. Because of that, the number of traumatic impacts detected on each skeletal element had to be compared with the number of those elements present in the studied material. The total number of skeletal elements that were included in the analysis is 193, and out of that, on thirty- six elements traumatic lesions were found.

4.4.2. Biological profile:

The estimated biological profile of the whole material shows that the youngest person was below 18 years of age at the time of death, and the oldest was over 60 at death. The biological sex estimated from coxal bones, which are the best elements to show sexual dimorphism, indicate that all individuals were males. Conversely, the number of preserved coxal bones is lower than the number of preserved skulls and femurs, with only 26 right and 24 left bones. The stature ranged from 161 to 180 cm. The ancestry estimation was possible only for eight skulls, and seven of them rendered a result European. One skull result was different from the European. However, additional studies should be performed to verify that outcome.

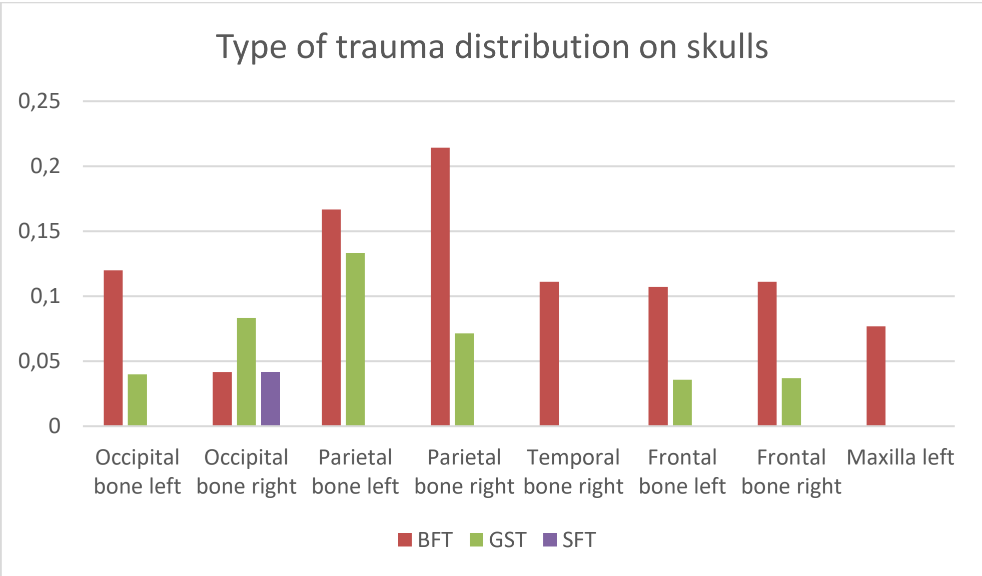

Figure 4. Trauma type (BFT- blunt force trauma; GST- gunshot trauma; SFT- sharp force trauma) frequency and distribution on skulls.

The minimal number of studied skulls is thirty- four. For thirteen skulls (38 %), it was impossible to estimate any component of the biological profile. For fourteen skulls (41%) it was impossible to evaluate age at death, for eighteen skulls (53%) it was not possible to estimate the biological sex. Thirteen skulls (38%) fell in the age-at-death category 18-30, five skulls (15%) have an estimated age-at-death 31-45, and two skulls

(6%) were over the age of 46 at death. Fourteen skulls (41%) were estimated as biological males or possible males, two skulls (6%) had morphological traits of the possible female sex, one of them was of a young age category, and the other was too damaged for age-at-death estimation. There was no skull of the definite female sex present (table 1). When adding genetic results (table 2) we see confirmation of anthropological finding that there was no definite female individual present in the studied sample.

Table 1. Age and sex distribution in the studied sample.

Age group	Males		Possible males		Possible females		Unknown sex		Total	
	N	%	N	%	N	%	N	%	N	%
18-30	1	2.94	9	26.47	1	2.94	2	5.88	**13**	**38.24**
31-45	2	5.88	1	2.94	0	0.00	2	5.88	**5**	**14.71**
46+	0	0.00	1	2.94	0	0.00	1	2.94	**2**	**5.88**
Unknown age	0	0.00	0	0.00	1	2.94	13	38.24	**14**	**41.18**
Total	**3**	**8.82**	**11**	**32.35**	**2**	**5.88**	**18**	**52.94**	**34**	**100.00**

N-number of cases

%- percentage of the whole sample

Table 2. The genetic and anthropological results comparison (XY- male; XY?- possible male; XX?- possible female; NA- not applicable, the biological sex could not be estimated; + presence of PCR inhibitors confirmed by RT-PCR; - presence of PCR inhibitors not confirmed by RT-PCR).

Skull nr:	Anthropological sex:	Genetic sex:	mtDNA haplogroup estimates:	Human DNA concentration and presence of PCR inhibitors:
G.206	-	XY	no result acquired	⩽ 1 ngμL; -
G.207	XY?	XY	R0	⩽ 1 ng/μL; -
G.208	XY?	XY	not studied	⩽ 1 ng/μL; -
G.209	XY	XY	not studied	⩽ 1 ng μL; -
G.212	-	XY	no result acquired	⩽ 1 ng/μL; -
G.214	XY?	XY	no result acquired	⩽ 1 ng/μL; +
G.215	XY?	XY	R0	⩾ 1 ng/μL; -
G.216	XY?	XY	not studied	⩽ 1 ng/μL; -
G.219	XY?	XY	no result acquired	⩽ 1 ng/μL; +
G.220	XY?	XY	not studied	⩾ 1 ng/μL; -
G.221	XY?	XY	no result acquired	⩽ 1 ng/μL; -
G.222	XY?	XY	U3	⩽ 1 ng/μL; -
G.223	XY	XY	not studied	⩾ 1 ng/μL; -
G.224	XY?	XY	HV1	⩽ 1 ng/μL; -
G.225	-	XY	no result acquired	⩽ 1 ng/μL; -
G.226	XY?	XY	not studied	⩽ 1 ng/μL; -
G.227	-	XY	not studied	⩽ 1 ng/μL; -
G.303	XX?	XY	not studied	⩽ 1 ng/μL; -
G.304	XY	XY	not studied	⩽ 1 ng/μL; -
G.400	-	XY	no result acquired	⩽ 1 ng/μL; -

G.404	-	XY	K1a1b1a	⩽ 1 ng/μL; -
G.408	-	XY	K1a1b1a	⩾ 1 ng/μL; -

4.4.3. Trauma study results:

Out of 34 studied skulls, 18 showed perimortem trauma marks. The lesions margins manifest obtuse and acute angles, the fracture edges are usually sharp, the color of the fracture edge is dark, similar to the surrounding bone color. The most common fracture type in the studied sample was linear and radiating. The fracture lines went in various directions of the skull, some followed the suture lines. Because of the fragmentary preservation state it was impossible to measure each of the fracture lines. In one case (skull nr G.304) the blunt force trauma located on sagittal suture was in the form of a crater like defect of dimensions 1,5x1,9 cm. It was the second of two blows detected on this skull, the first blow was on the occipital bone. The aforementioned defect could be the remnant of a concentric fracture, with bone pieces filling the crater lost postmortem.

The trauma results show that the highest number of impacts (9 blows) were located on the right parietal bone. All of those impacts were caused by blunt force trauma (BFT). On the left parietal bone there are also nine injuries, but only five of them were caused by blunt force trauma, and the remaining four were gunshot (GST) entry injuries. In total, there were eight gunshot entry trauma detected, and only three exit trauma. As already mentioned, four impacts were located on the left parietal bone, three were on the occipital bone (two were on the right side, one on the left), and one entry wound was on the frontal bone on the right side. Whereas the exit wounds were located on the right parietal bone and the left side of the frontal bone. There was only one sharp force trauma (SFT) detected and its location was on the occipital bone. There was no perimortem trauma found on the maxilla right and temporal left bones.

A. Impact frequency.

In the youngest age group (18-30), twenty blunt force trauma impacts were observed on eight skulls, two gunshot trauma were present on two skulls. There are no other types of trauma detected in that age group sample. In the older age category (31-45), the number of blunt force trauma impacts is lower, with three impacts on one skull, and only one sharp force trauma on one skull. The total number of individuals in that age category is much lower (5 people) than in the younger one (13 people). In the oldest age group, there are three blunt force trauma impacts on one skull and two gunshot trauma on another skull. Additionally, in the group of skulls of unknown age-at-death, one blunt force trauma impacts were present on one skull and six gunshot trauma on five skulls (fig. 5). Although the highest number of trauma impacts were detected in the youngest group of studied individuals, the highest trauma frequency is seen in the older age ranges, as there are far fewer individuals in those age groups present (fig. 6).

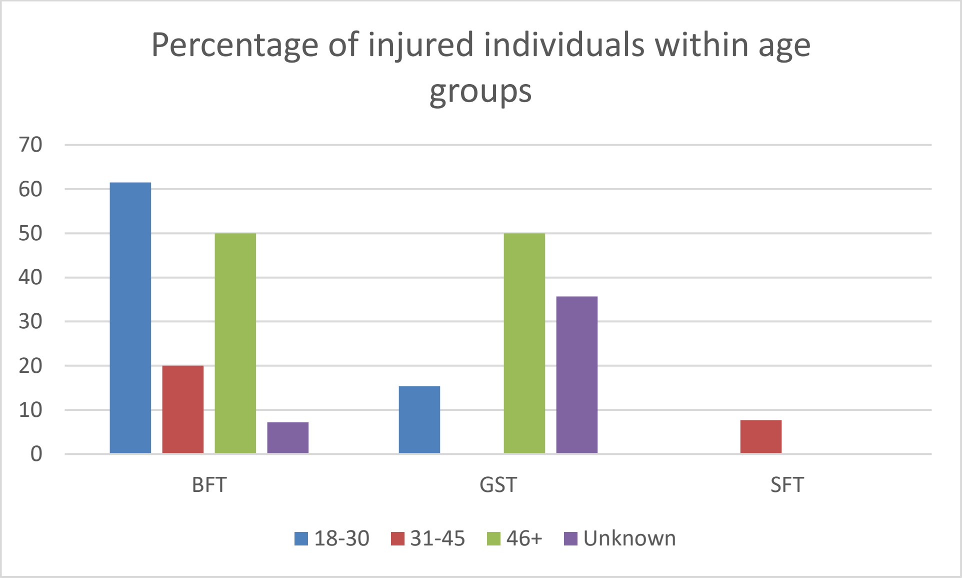

Figure 5. Percentage of injured individuals with regard to age categories and trauma type (BFT- blunt force trauma; GST- gunshot trauma; SFT- sharp force trauma).

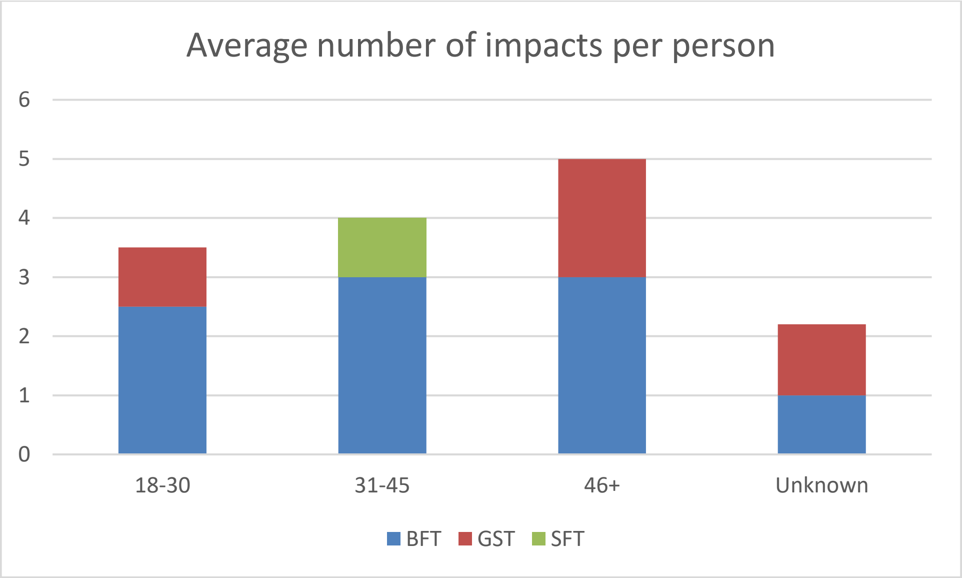

Figure 6. The average impact frequency of different trauma type (BFT- blunt force trauma; GST- gunshot trauma; SFT- sharp force trauma) per person within estimated age categories.

The highest number of impacts were caused by blunt force trauma (eleven skulls), followed by gunshot trauma (eight skulls). Three skulls showed only one point of impact caused by blunt force trauma. On eight skulls multiple points of impact were observed, caused by a blunt instrument. Two skulls showed multiple gunshot injuries. Two skulls manifest combination of blunt force trauma and gunshot trauma. On one skull of a young male (over 20 years old at the time of death), there were visible multiple (at least four) blunt force trauma impacts and a gunshot injury (fig. 8, 9).

B. Gunshot trauma.

The bullet trajectories in cases of gunshot trauma were possible to follow only in one case, where the entry wound was on the left parietal bone and the exit on the frontal bone, but in that case there was one exit wound too many, that was located on the right parietal bone. In one case, it can be inferred that the bullet exited through the foramen magnum, as the entry hole was in the frontal bone and all the other skull elements were intact. In one of the cases, only an exit gunshot wound was present, located on the right parietal bone. In five skulls, the entry gunshot defects were present without any exit wounds. In three skulls, the entry wound was on the occipital bone, and on the three was on the left parietal bone. One skull had two entry wounds, one on the occipital and one on the left parietal bone. The measured diameter of all entry wounds is 9 mm, the maximum diameter of exit wounds crater was, in average, 14 mm in the inner side of the defect and 19 mm in the external crater boarder. All entry wound displayed a beveling on the inner side of the cranial bone, and all the exit wounds demonstrated a crater shaped defect, beveling, on the outer side of the cranial bone.

C. Postcranial traumatic lesions.

On the postcranial elements, perimortem fractures were detected on two out of twenty- five present right humeral and one out of twenty four left humeral bones. On the right side, one exhibited a spiral fracture (fig. 7) and only the proximal third of the bone was preserved, and the other bone was fractured obliquely and the distal two thirds of the bone is present. The left humerus was fractured in transverse complete fracture type and the distal half is only present. There was no other trauma lesion detected in the whole studied assemblage.

Figure 7. Right humerus perimortem spiral trauma G 71.

D. Genetic study results:

For each step of genetic analyses (DNA isolation, quantification, amplification, capillary electrophoresis, mitochondrial DNA testing), negative controls showed no result and positive controls showed correct profiles. No match was detected between the mitotypes of victims and the database of haplotypes of all persons involved in the study.

The quantity and quality parameters of DNA extracts obtained from studied skulls are shown in Table 2, above (detailed results are shown in appendix table 10) and indicate a < 1 ng/ µL DNA concentration in samples from 82 % (18/22) of the victims. In two samples the presence of PCR inhibitors was confirmed by the RT-PCR method. For those samples, expectedly, no results in mtDNA testing was obtained.

Results of DNA quantification for several samples indicate quite high human DNA yields (see appendix Table 10), however mitochondrial DNA sequencing was successful only for a few of the samples. That might be due to a possible low tolerance of various elements of the kits used for mitochondrial DNA testing for the presence of PCR inhibitors in the samples, especially as genetic sex typing was successful for many of the samples tested with commercially available STR typing kits (see table 2). Even though some PCR inhibitors can be detected with the Quantifiler ™ Human DNA Quantification Kit, the unelevated value of the IPC system does not exclude the possibility of their presence, especially calcium, which is a known and common inhibitor in bone extracts [63]. Additionally, some level of DNA degradation is expected, which may hinder the results and be causative of stochastic effects, where the quantity of DNA measured may not be representative of the whole sample. This degradation would also not be visible in DNA quantification results as the Quantifiler ™ Human DNA Quantification Kit is indicative of fragments only 62 bp long.

4.5. Discussion.

At the time of writing, eighty- two years have passed since the executions at KL Stutthof, but the identity of the victims and the cause and manner of their death still remains unknown. The study's goal was to examine and interpret perimortem trauma noticed on skeletal remains of the victims who were buried in mass graves in the forest near the former Stutthof concentration camp. The results hope to reveal the victims' circumstances of death as well as the position and attitude of the perpetrators towards the victims. Additionally, the determination of the victims' cause of death will benefit the process of prosecution of war crimes [64].

The victims' biological profile is consistent with the numerous published historical sources describing the people who were killed in the Stegna forest in 1940. Mitotypes of six victims were assigned to four mtDNA haplogroups: HV1 (one victim), R0 (two victims), U3 (one victim) and K1a1b1a1 (two victims). Since only hypervariable fragments 1 and 2 were studied, and thus the haplogrouping results obtained are only estimates, some conclusions can still be drawn. All four haplogroups are descendants of haplogroup R, which is associated with the colonizing of the Eurasia [65]. The frequency of HV haplogroup (excluding haplogroups H and V) is higher in the Near East and the Caucasus, however it can also be found in southern and eastern Europeans – Belarussians, Bulgars, and Italians [66]. The "R0" result (as stated in the Material and methods section here understood as all lineages descending from R0), although highly unspecific, points to a rather West Eurasian origin [67]. Haplogroup U3 is found predominantly in Russia, East Europe and the Balkans (> 40%), as well as in the Near East (> 30%), West Europe, Central Asia, The Caucasus and South Europe (> 20%), Middle East, North Europe and East Africa (> 10%) and rarely in Arabia and West Africa (< 10%). It has to be noted that although the determining mutation of U3 (16343G) was found in the haplotype of G.222, the position itself is believed to be unstable [65]. K1a1b1a is known as one of the three main lineages of Ashkenazi Jews that constitute up to 20% of all Ashkenazi lineages, however three of its defining mutations lay outside of the studied region [68].

The biggest difficulties in assessing the profile's components were caused by the preservation state of diagnostic skeletal elements [69]. This problem highlights the importance of multidisciplinary approach when working with degraded commingled and fragmentary skeletal material. Whereas for some components of the biological profile evaluation might help DNA analysis, skeletal trauma diagnosis still remains the expertise of forensic anthropologists.

Our trauma analysis shows that the prevalent killing method in the KL Stutthof sample was blunt force trauma to the head, as the rib cage trauma had to be excluded from the analysis (it was impossible to associated singular rib with particular skeleton, nor was it possible to determine time of the trauma occurrence on majority of the fractured ribs). The majority of the perimortem lesions were found above the hat brim line (HBL), which is a common indicator of a violent attack in medico-legal studies [70], [71]. The HBL rule can be debatable in the scientific community [72], [73] in terms of a violence determinant. However, in our case, it is further supported by multiple impact points visible on several skulls. The prevalence of the right parietal bone trauma marks over the left parietal ones (fig. 4) can mean that the attacker was standing behind the victim during the attack, or that the perpetrator was a left-handed person [74]. The weapon reconstruction was not possible, but, given the presence of radiating and concentric fractures, we suspect that the killing object was of a relatively small surface area [75], such as a rifle butt, a hammer, a bat etc. The presence of many linear fractures on the cranial vault can indicate that the skull was not immobilized against, for example, a hard surface when the blow occurred [76].

Blunt force trauma is one of the most commonly encountered types of trauma by medical doctors and forensic specialists. It is also one of the most difficult type of injury to interpret because it may be manifested in various ways depending on the skeletal element that is affected, the impact force and the tool used [77], [78]. Depressed fractures are usually created by a slow loading force on the small area of the skull [75] and are often associated with a violent attack [79].

Identical interpretation can be applied to the location of many gunshot entry wounds, on the occipital bone, and posterior parietal bone, which means a shot to the back of the head, that in turn is often associated with executions [80].

The absence of perimortem fractures on forearm bones and hand bones can indicate that the victims did not fight back during the executions [81]. It is possible that they were taken by surprise or that their arms were held tight, preventing any defensive movements. Defense wounds happen in less than a half of violent attacks [82] and they don't necessarily mean skeletal fractures. Therefore, we cannot determine whether the victims tried to defend themselves or not. However, the complete lack of defensive fractures observed on forearm bones and hand bones may suggest a surprise attack or hands restraining. Humeral fractures observed in three bones could happen during the restraining of the victims' arms by the aggressors. In particular, the spiral fracture could be the result of such a mechanism. Spiral long bone fractures usually are the result of one end of the bone immobilized in one position and the other end twisted, or both ends twisted in the opposite directions [15]. What's more, the other bones that were fractured could be the effect of a beating with a blunt object. On the other hand, those fractures could be the result of tossing the bodies in the grave after death.

As noted by Baraybar [64] in his works on International Humanitarian Law violations, the context of the remains discovery is vital for forensic anthropologists and pathologists in the trauma analysis process that leads to the determination of cause and manner of death by forensic pathologists. In our study, neither a forensic anthropologist nor a forensic pathologist was present during the remains recovery process, which in turn has affected our trauma analysis results.

State-sponsored violence is getting more attention within the scientific community with regards to skeletal perimortem trauma patterns [16], [27], [80]. In her dissertation [16] on Soviet army violence, Bird noticed that in the early stages of the aggressors' occupation the prevalent execution methods were mainly gunshots, and over time, blunt force trauma methodology became more frequent. Szleszkowski, in his studies done also on Soviet soldiers' methodology [80], observed the application of single shots to the back of the head or multiple gunshot trauma executed by a firing squad. Blunt force trauma is considered a more personal type of attack than a ballistic trauma. For that reason, state-regulated executions applied shootings as a preferred killing method. Our study shows a higher prevalence of blunt injuries over ballistic trauma. Those kinds of violence are commonly encountered in the 20th century political conflicts (Ukraine, Bosnia, Cambodia, Rwanda), and are based on the assumption than the target group had received unfair advantage in the past [83], so the act of violence is acceptable as a revenge. Figurative transformation of the oppressed group makes them being seen as malignant. Therefore the non-violent group members must be eliminated on the basis of future risk. The attackers' brutality is particularly shown in the skull of one young male in our studied sample, who had lesions from at least four blunt force impacts and a gunshot trauma with entrance wound at the top of the head (near the coronal and sagittal sutures junction). Overkill trauma is defined as trauma that exceeds the necessary amount of blows to kill the person [84]. It is usually manifested by multiple perimortem injuries that can effect in destruction of large parts of the cranium [85].

Figure 8. Skull number G 214 lateral view.

Figure 9. Skull number G 214 superior view with a gunshot entry trauma.

Commingled remains pose difficulties for forensic specialists both in personal identification and trauma analysis [45]. On the other hand, in more recent times, there are a growing number of cases where commingling is present, such as transportation accidents, natural disasters and intentional commingling done after genocide to hide the evidence of a crime [86]. There is a common belief among many forensic specialists, such as archaeologists and crime scene investigators, that anthropologists can separate all bones belonging to each skeleton after commingling. Thus, even when the commingling wasn’t present on the scene, frequently anthropologists receive bones from many individuals packed commingled in one bag. That happened as well in our studied case. The remains were in anatomical order when in the grave, and became commingled and put in two sarcophagus placed under the monument waiting from the exhumation in 1979 till the analysis performed by PMU specialists in 2018.

Oftentimes, in forensic scenarios, anthropologists are required to work with fragmentary remains [87], [88]. Fragmentation can happen either perimortem as a result of trauma, or postmortem due to taphonomic alterations, human action, animal activity or plant interference. Those postmortem changes can, in turn, resemble perimortem injuries and cause misinterpretation of the trauma pattern performed by a forensic expert [89]. Fragmentation of the skeletal remains often leads to incomplete recovery from body deposition or a crime scene and eventually to limited biological profile components estimations and trauma analysis [90]. This was another problem we had to deal with in our research, as the majority of the study material was fragmented and incomplete, especially the skulls. On many crania it was impossible to follow the bullets’ trajectories, as there were too few fragments preserved, and solely either exit hole or entry hole was present on the recovered bone element.

Both blunt force trauma and gunshot trauma can result in radiating and concentric fractures in the skull [91]. One possibility to discern one type of trauma from another is by reconstructing the fractured cranial fragments back together and seeing how the fractured pieces match. In cases of blunt force trauma, usually the reconstruction is imperfect [42], whereas in gunshot trauma, bone fragments can be reassembled together like glass [92]. Working only on cranial fragments from incomplete skulls always poses problems with trauma analysis and interpretation, so the researcher should be aware of trauma over-interpretation possibilities [93]. Additionally, in our case, the skulls went through postmortem alterations, such as compression in the grave caused by layers of soil and/or other bodies, and compression in the sarcophagus. That also contributed to the risk of errors during the perimortem trauma analysis process.

In forensic anthropology and forensic pathology, the terms indicative of the trauma time occurrence are usually divided into antemortem, perimortem and postmortem [94]. The word perimortem has different meanings for forensic pathologists and forensic anthropologists [71]. In forensic medicine, perimortem means at or around the time of death and is usually associated with the event of death. In forensic anthropology, perimortem has an extended time of occurrence because it means trauma that happened on fresh, hydrated bone [58] which, depending on environmental conditions, can last long after death. If the decomposition process happens in an aquatic environment, bone can retain a fresh state appearance longer, which can influence trauma assessment [95]. Our studied material was exhumed quite late after the killings (almost forty years later), because the environmental conditions, such as seasonal flooding and marshes, prevented access to the grave. Prolonged immersion of skeletons could result in wrongful trauma time assessment performed by forensic specialists, which was another obstacle in our study that we were aware of.

CT scans of dry bones serve not only as a morphological preservation agent but also as a trauma time determinant [71], [96]. The biggest advantage of radiological analysis is the ability to access the hidden structures of the skeleton, such as the sinuses, or teeth cavities. That quality is of the highest importance in perimortem trauma pattern analysis. As the identification process doesn't end in anthropological studies, but also includes invasive molecular methods like a DNA analysis or an isotope analysis, the morphological structure of the bones will be destroyed in the course of those studies. Thus, it is recommended to perform CT scans which allow the preservation of skeletal morphological features in three dimensions, before the bone is destroyed by other forensic specialists. Radiological techniques offer precise tools in perimortem trauma assessment, though, two conditions must be met. First, the scanning settings must be adjusted for dry bone scanning [59], secondly, the researcher must be trained in radiology in order to properly read and analyze the results [97]. In our study, we applied the recommended scanning settings, and the scanning images were studied by three specialists altogether: an anthropologist, a medical pathologist and a medical radiologist.

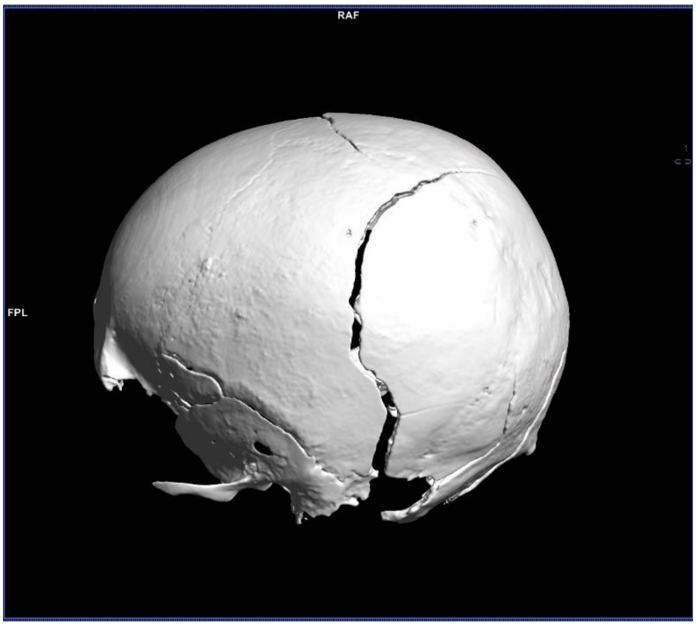

Figure 10. Skull number G 219 lateral view.

From our study material we can observe taphonomic changes typical for mass grave decomposition [98]. On several skeletal elements, we can see plant roots etching, some bones are smooth and well preserved, and others retain mummified or saponified soft tissues. Three bodies arrested the decomposition process at saponification, so the skeletons could only be studied radiologically. Moreover, after the exhumation process, the bones were stored and sealed in two coffins with only rodents being able to access them (what is proved by traces of rodents nests in the skulls). Those conditions allowed for microorganisms such as fungi to proliferate on bones. All these conditions influenced DNA recovery.

No positive identification has been rendered yet, as there was no match between the reference material obtained from families and profiles obtained through skeletal material analysis. It may be possible, that the only plausible method of identification will be anthropological analysis. For future research, we recommend performing forensic facial approximation or a superimposition technique with the preserved photographs of the suspected victims. Future genetic studies are planned to further investigate the biogeographic origin of the victims exhumated on the grounds of the former KL Stutthoff concentration camp. Those will include the incorporation of the mitotiling amplification technique and Next Generation Sequencing. This will allow for a much higher resolution of mitochondrial haplogrouping through whole mitogenome sequencing, regardless of high DNA degradation and low DNA quantity [99]–[102].

4.6. Conclusion.

Our analyses showed that even in commingled skeletal assemblage, it is possible on the cause and manner of death inference thus contributing to criminal proceedings of delayed crime investigations. With the application of modern forensic science technology it is possible to solve crimes committed more than eighty years ago. In complex criminal scenarios such as the Stutthof case was, it is crucial to employ multidisciplinary approach, allowing to answer multiple research questions at once.

The skeletal material proves being a hard evidence of a committed crime. Our trauma examination show that the victims were probably hit from behind with a blunt instrument or shot to the back of their heads. Given the variety of traumatic lesions encountered in the studied sample, we can suspect multiple assailants present during the killing. The multiple impact points on many skulls as well as a combination of different types of trauma are clear signs of brutality of the execution process and that it exceeded the state-sponsored execution protocol and is a clear proof of the ethnic cleansing project that happened in the free city of Danzig between 1939 and 1942. The presented results open perspectives for future research of other genocide mass burials.

4.7. Supplement.

Table 1. Femoral bones inventory.

No.	Preservation	Side	Segment	Age	Sex	Max. length [mm]	Head diameter [mm]	Neck length [mm]	Neck diameter [mm]
G.1	1	R		20+	M	471	49	103	33
G.2	1	R		20+	?	443	44	85	34
G.3	1	R		20+	M?		47	94	32
G.4	1	R		14-16	?	435			
G.5	1	R		20+	M?	471	45	92	33
G.6	1	R		20+	F?	417	44	91	30
G.7	1	R		20+	F?	412	43	89	32
G.8	1	R		20+	M?	441	46	93	32
G.9	1	R		20+	M?	445	46	99	36
G.10	1	R		20+	F	436	42	89	31
G.11	1	R		20+	?	433		84	
G.12	1	R		20+	M?	460	47	97	34
G.13	1	R		20+	M?	421	44	91	34
G.14	1	R		20+	?	408	44	90	32
G.15	1	R		20+	M	485	47	96	37
G.16	1	R		20+	M	454	48	92	35
G.17	1	R		20+	M	471	49	100	38
G.18	1	R		20+	F	412	41	91	28
G.19	1	R		20+	M?	467	45	98	32
G.20	1	R		20+	M?	449	46	93	34
G.21	2	R	Chipped proximal part	20+	?			90	
G.22	1	R		20+	M?	431	46	96	31
G.23	1	R		20+	M	427	52	99	35
G.24	1	R		20+	M?	427	47	92	33
G.25	1	R		17-20	M?		46	94	34
G.26	1	R		20+	F?	442	43	93	30
G.27	1	R		20+	M	483	49	107	38

G.28	1	R		20+	F?	427	44	86	31
G.29	2	R	Chipped proximal part	20+	F?	422	42	89	
G.30	3	R	D1/5	20+					
G.31	2	R	diaphysis 2/3						
G.32	2	L	Diaphysis 1/2						
G.33	1	L		20+	M?	435		86	34
G.34	1	L		20+	M	464		103	33
G.35	1	L		20+	M?	444	44	97	36
G.36	1	L		20+	F?	426	45	87	31
G.37	1	L		20+	M	417	48	90	35
G.38	1	L		20+	M?	467	45	97	33
G.39	2	L	P1/2	19+	M		50	99	33
G.40	1	L		20+	?	410	44	91	32
G.41	1	L		14-19	?	451			
G.42	1	L		20+	?	427	42	92	30
G.43	1	L		20+	F	416	41	95	28
G.44	1	L		20+	M	454	47	99	32
G.45	2	L	D1/2	20+					
G.46	1	L		20+	M?	429	44	92	33
G.47	1	L		20+	?	410			
G.48	1	L		20+	M	489	53	101	39
G.49	1	L		20+	F	441	42	92	28
G.50	1	L		20+	M	484	47	99	36
G.51	1	L		20+	M?	457		94	34
G.52	1	L		20+	?	438	44	86	33
G.53	1	L		20+	?	441	44	93	30
G.54	1	L		20+	M?	453	47	92	34
G.55	1	L		20+	M	471	51	100	36
G.56	1	L		20+	M	446	48	97	34
G.57	1	L		20+	F?	412	43	87	32
G.58	1	L		20+	M?	462	46	97	32
G.59	1	L		20+	M	480	48	107	37

G.60	2	L	Head missing	20+					
G.61	1	L		20+	F?	435		89	30
G.62	2	L	P1/2	19+	M?		47		
G.63	1	L		20+	?	480	45	91	32
G.228	1	L		20+	M?	455	46	95	33

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 2. Tibia bones inventory.

No.	Preservation	Side	Segment	Age	Max. length [mm]
G.108	1	R		19+	356
G.109	1	R		19+	340
G.110	1	R		19+	367
G.111	1	R	Chipped distal epiphysis	19+	
G.112	1	R		19+	338
G.113	1	R		19+	346
G.114	1	R		19+	366
G.115	1	R		19+	336
G.116	1	R		19+	309
G.117	1	R		19+	342
G.118	1	R		19+	341
G.119	1	R		19+	317
G.120	1	R		19+	368
G.121	1	R		19+	346
G.122	2	R	P2/3	19+	
G.123	1	R		19+	319
G.124	1	R		19+	347
G.125	1	R		19+	327
G.126	1	R		19+	333
G.127	1	R		12-18	351
G.128	1	R		19+	358

G.129	1	R		19+	367
G.130	1	R		19+	355
G.131	1	R		19+	334
G.132	1	R		19+	317
G.133	1	R		19+	340
G.134	1	L		19+	347
G.135	1	L		19+	331
G.136	1	L	Chipped distal epiphysis	19+	
G.137	1	L		19+	367
G.138	1	L		19+	341
G.139	1	L		19+	345
G.140	1	L		19+	368
G.141	1	L		19+	316
G.142	1	L		19+	324
G.143	1	L		19+	333
G.144	1	L		19+	336
G.145	1	L		19+	368
G.146	1	L		19+	338
G.147	1	L		19+	319
G.148	1	L		19+	363
G.149	1	L		19+	359
G.150	1	L		12-18	357
G.151	1	L		19+	334
G.152	1	L		19+	327
G.153	1	L		19+	340
G.154	1	L		19+	344
G.155	1	L		19+	368
G.156	1	L		19+	332
G.157	1	L		19+	315
G.158	1	L		19+	337
G.159	1	L		19+	357

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.

Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 3. Humeral bones inventory.

No.	Preservation	Side	Segment	Age	Sex	Max. length [mm]	Head diameter [mm]
G.64	1	R	Chipped distal epiphysis	20+	F		42
G.65	1	R		20+	F	314	42
G.66	1	R		20+	F?	307	43
G.67	1	R		20+	F	286	41
G.68	1	R		20+	?	333	45
G.69	1	R		20+	M	321	47
G.70	1	R		20+	?	308	45
G.71	3	R	P1/3	20+	F		42
G.72	1	R	Chipped distal epiphysis	20+	F		41
G.73	2	R	Fractured proximal epiphysis	20+			
G.74	1	R		20+	M	302	48
G.75	2	R	D2/3	19+			
G.76	1	R		20+	?	320	44
G.77	1	R		20+	?	306	45
G.78	1	R	Chipped epiphyses	20+			
G.79	1	R	Chipped proximal epiphysis	20+			
G.80	1	R		20+	M	301	47
G.81	1	R		20+	?	315	45
G.82	1	R		20+	?	300	44
G.83	1	R		20+	F	318	43
G.84	1	R		20+	?	302	46
G.85	2	R	D2/3	19+	?		
G.86	1	L		20+	F	285	42

G.87	1	L		20+	F	312	41
G.88	1	L		20+	?	328	45
G.89	1	L	Chipped epiphyses	20+			
G.90	2	L	D4/5	19+			
G.91	1	L		20+	M	329	47
G.92	1	L		20+	?	290	44
G.93	1	L	Chipped proximal epiphysis	20+			
G.94	1	L		20+	F	317	43
G.95	1	L		20+	M	329	47
G.96	1	L		20+	M	336	48
G.97	1	L		20+	F	310	43
G.98	1	L		20+	M	308	48
G.99	1	L		20+	?	302	46
G.100	2	L	D1/2	19+	?		
G.101	1	L		20+	?	300	46
G.102	1	L	Chipped epiphyses	20+			
G.103	1	L		20+	F	311	43
G.104	1	L	Chipped epiphyses	20+			
G.105	1	L		20+	?	330	45
G.106	1	L		20+	F	302	43
G.107	1	L	Chipped epiphyses	20+			
G.250	1	R		17-20			
G.251	2	R	D1/2	17+	?		
G.252	3	?	Only head	20+	?		
G.253	1	L		20+		295	
G.254	1	R		20+	?	336	45
G.255	1	L		20+	M	317	47

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 4. Ulna bones inventory.

No.	Preservation	Side	Segment	Age	Max. length [mm]
G.286	1	R		20+	241
G.287	1	R		20+	241
G.288	1	R	Fractured proximal epiphysis	<20	
G.289	1	R		20+	228
G.290	1	R	Fractured styloid	20+	
G.291	1	R	Fractured proximal epiphysis	20+	
G.292	1	R	Fractured styloid (ante/perimortem)	20+	
G.293	1	R	Fractured styloid and proximal epiphysis	20+	
G.294	1	R	Fractured styloid	20+	
G.295	1	R	Fractured styloid	20+	
G.296	1	L		20+	238
G.297	1	L	Fractured proximal epiphysis	<20	
G.298	1	L	Fractured styloid and proximal epiphysis	20+	
G.299	1	L		20+	258
G.300	1	L		20+	250
G.301	2	L	Fractured distal epiphysis	16+	
G.302	2	L	Fractured distal epiphysis	16+	
G.331	2	R	Lack of distal epiphysis	16+	
G.332	2	R	Fractured distal epiphysis	16+	
G.333	1	R	Missing styloid	20+	
G.334	1	R		20+	230
G.335	1	R	Missing styloid	20+	
G.336	1	R		20+	250
G.337	2	R	Fractured distal epiphysis	16+	
G.338	1	R		20+	248
G.339	1	R	Missing styloid	20+	
G.340	2	R	Fractured distal epiphysis	16+	
G.341	1	L	Missing styloid	20+	

G.342	1	L		20+	243
G.343	2	L	Fractured distal epiphysis	16+	
G.344	2	L	Fractured distal epiphysis	16+	
G.345	1	L	Missing styloid	20+	
G.346	1	L		20+	245
G.347	1	L	Missing styloid	20+	
G.348	1	L		20+	236
G.349	2	L	Fractured distal epiphysis	16+	
G.350	1	L		20+	249
G.351	2	L	P3/4	16+	
G.352	1	L	Missing styloid	20+	
G.353	1	L		20+	248

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 5. Radius bones inventory.

No.	Preservation	Side	Segment	Age	Max. length [mm]
G.256	1	R	Missing styloid	20+	
G.257	1	R	Missing styloid	20+	
G.258	1	R		20+	226
G.259	1	R		20+	223
G.260	1	R	Missing styloid	20+	
G.261	1	R	Missing styloid	20+	
G.262	1	R		20+	228
G.263	1	R		20+	232
G.264	1	R		20+	229
G.265	1	R		20+	240
G.266	1	R	Missing styloid	20+	
G.267	1	R		20+	225
G.268	1	R		20+	242

G.269	1	R	Missing styloid	20+	
G.270	1	R		20+	231
G.271	1	R		<17	225
G.272	1	R		20+	211
G.273	1	L	Missing styloid	20+	
G.274	2	L	M1/2	?	
G.275	2	L	D3/4	20+	
G.276	1	L		20+	230
G.277	2	L	Missing styloid and caput	20+	
G.278	1	L		20+	238
G.279	1	L		20+	232
G.280	1	L	Missing styloid	20+	
G.281	1	L		20+	235
G.282	1	L	Missing styloid	20+	
G.283	1	L		20+	210
G.284	1	L		20+	220
G.285	1	L		<17	220
G.319	1	R		20+	254
G.320	1	R		20+	213
G.321	1	R		20+	238
G.322	1	R		20+	234
G.323	1	L	Missing styloid	20+	
G.324	1	L	Missing styloid	20+	
G.325	1	L		20+	225
G.326	1	L		20+	229
G.327	1	L		20+	234
G.328	1	L		20+	229
G.329	1	L		20+	227
G.330	1	L		20+	230

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 6. Fibula bones inventory.

No.	Preservation	Side	Segment	Age	Max. length [mm]
G.249	2	R	D3/4	18+	
G.354	2	R	D4/5	18+	
G.355	1	R		20+	342
G.356	1	R	Fractured P1/3	20+	
G.357	1	R	Fractured D1/3	20+	
G.358	1	R	Fractured proximal epiphysis	20+	
G.359	1	R		20+	340
G.360	1	R	Fractured proximal epiphysis	20+	
G.361	1	R	Fractured proximal epiphysis	20+	
G.362	1	R	Fractured proximal epiphysis	20+	
G.363	2	R	D3/4	18+	
G.364	1	R		20+	345
G.365	1	R	Fractured proximal epiphysis	20+	
G.366	1	R	Fractured proximal epiphysis	20+	
G.367	1	R	Fractured proximal epiphysis	20+	
G.368	1	R	Fractured proximal epiphysis	20+	
G.369	1	R	Fractured proximal epiphysis	20+	
G.370	2	R	D3/4	18+	
G.371	1	R	Fractured proximal epiphysis	20+	

G.372	1	L	Fractured proximal epiphysis	20+	
G.373	1	L	Fractured proximal epiphysis	20+	
G.374	1	L	Fractured proximal epiphysis	20+	
G.375	1	L	Fractured proximal epiphysis	20+	
G.376	2	L	D3/4	18+	
G.377	1	L		20+	334
G.378	2	L	D3/4	18+	
G.379	1	L		20+	321
G.380	1	L	Fractured proximal epiphysis	20+	
G.381	2	L	D3/4	18+	
G.382	1	L	Fractured proximal epiphysis	20+	
G.383	1	L	Fractured epiphyses	20+	
G.384	2	L	D3/4	18+	
G.385	1	L		20+	365
G.386	1	L		20+	333
G.387	1	L		20+	357
G.388	1	L	Fractured proximal epiphysis	20+	
G.389	2	L	D3/4	18+	
G.390	1	L	Fractured proximal epiphysis	20+	
G.391	1	L	Fractured proximal epiphysis	20+	
G.392	2	L	P3/4	20+	
G.393	2	R	M3/4	?	
G.394	2	L	D3/4	18+	
G.395	1	L	Fractured epiphyses	20+	
G.396	2	L	D3/4	<18	

G.397	2	R	P2/3	20+	
G.398	2	R	M3/4	?	
G.399	2	R	D3/4	<18	

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 7. Hip bones inventory.

No.	Preservation	Side	Segment	Age	Sex
G.160	1	R		30-34	F
G.161	2	R	Fragment ilium+ischium	?	F?
G.162	2	R	Fragment ilium+pubis	35-44	?
G.163	2	R	Fragment ilium+ischium	20-30	?
G.164	1	R		40-66	M
G.165	1	R		35-45	F
G.166	2	R	Fragment ilium+ischium	20-35	?
G.167	1	R		25-34	?
G.168	1	R		35-57	M
G.169	2	R	Fragments ilium+ischium+pubis	35-57	M?
G.170	3	R	Fragment ilium	30+	?
G.171	1	R		30-46	M
G.172	1	R		20-30	M
G.173	1	R		45-49	M
G.174	1	R		20-30	M
G.175	1	R		23-57	?
G.176	1	R		30+	M
G.177	1	R		50+	?
G.178	2	L	Fragment ilium+ischium	30+	?
G.179	1	L		21-46	?
G.180	2	L	Fragment ilium+ischium	?	M?
G.181	1	L		30+	?

G.182	1	L		30+	?
G.183	3	L	Fragment pubis	?	M?
G.184	1	L		30-46	M
G.185	1	L		27-66	?
G.186	1	L		30+	M
G.187	1	L		34-86	M
G.188	1	L		25-34	M
G.189	1	L		<20	M
G.190	1	L		30+	M
G.191	1	L		20-25	?
G.192	1	L		21-46	M
G.193	1	L		23-57	M
G.194	1	R		21-46	M
G.195	1	L		34-86	M
G.196	1	L		40+	?
G.197	1	L		25-34	M
G.198	1	L		34-86	?
G.229	1	L		25-35	?
G.230	2	L	Fragment ilium+ischium	20-35	?
G.231	2	L	Fragment ilium+ischium	40-49	M?
G.232	1	L		20-30	M
G.233	1	L		23-57	M
G.234	1	L		35+	M
G.235	1	R		30-40	?
G.236	2	R	Fragment ilium+ischium	?	?
G.237	1	R		21-46	M
G.238	1	R		25-34	?
G.239	1	R		<20	M
G.240	1	R		30+	M
G.241	1	R		23-57	M

Side: R- right; L-left
Segment: P1/3- proximal third of diaphysis; M1/3- mid-third of diaphysis; D1/3- distal third of diaphysis etc.
Preservation: 1=>75%; 2=25-75%; 3=<25%

Table 8. Other postcranial elements inventory.

Element:	Number of rights:	Number of lefts:
Clavicle	17	8
Ribs	88	100
Sacrum	14	
Scapula	19	13
Patella	2	3
Foot	22	19
Hand	<10	
Vertebra	36 lumbar; 44 thoracic; 20 cervical + one full vertebral column	

Table 9. Skull inventory.

No.	Preservation	Segment	Age	Sex	Ancestry
G.206	1		18-30	?	European
G.207	1		18+	M?	European
G.208	1		25+	M?	European
G.209	1		30+	M	NS American
G.211	3	Left temporal bone	?	F?	
G.212	2	No facial bones, no cranial base	30+	?	
G.213	2	Frontal and parietal bones	50+	?	
G.214	1		20+	M?	
G.215	1		18+	M?	
G.216	1		20+	M?	
G.217	2	Frontal, both parietals and occipital	35+	?	
G.218	3	Frontal and right parietal	?	?	
G.219	2	No facial bones, no cranial base	45+	M?	
G.220	1		25+	M?	European
G.221	1		30+	M?	European

G.222	2	No facial bones, no right temporal and parts of right parietal is missing	18+	M?	
G.223	1		35+	M	European
G.224	2	No facial bones	18+	M?	
G.225	2	Frontal, both parietals, occipital, maxilla	?	?	
G.226	1		21+	M?	European
G.227	2	Occipital bone, temporal bones, fragments of parietal, frontal and zygomatic	20+	?	
G.303	1	No left temporal	18+	F?	
G.304	1		18+	M	
G.400	2	Part of occipital, left parietal, left temporal, part of frontal, part of right parietal	?	?	
G.401	3	Left parietal, part of frontal, part of right parietal	?	?	
G.402	3	Part of frontal, part of left parietal	?	?	
G.403	3	Occipital, part of let parietal, part of right parietal	?	?	
G.404	3	Part o occipital, part of both parietals, part of left temporal	?	?	
G.405	3	Left parietal, part of right parietal, part of frontal	?	?	
G.406	3	Part of frontal, part of left parietal	?	?	
G.407	3	Frontal bone, part of left parietal, part of occipital	?	?	
G.408	3	Part of occipital and right temporal, part of right parietal	?	?	
G.409	3	Parts of parietal and frontal	?	?	
G.410	3	Part of frontal, part of right parietal, part o left parietal	?	?	

Table 10. Quantity and quality parameters of DNA extracts obtained from studied skulls (IPC C_t- the number of the PCR cycle in which the fluorescence level for the VIC™ dye exceeds the threshold set for the internal PCR control system; according to the results of internal validation and the manufacturer's instructions, Ct≥ indicates the presence of PCR inhibitors within the sample).

Skull nr	Human DNA concentration [ng/μL]	IPC C_t
G.206	0,657	27,4
G.207	0,338	27,9
G.208	0,182	24,3
G.209	0,014	24,1
G.212	0,791	27,9
G.214	0,300	31,1
G.215	1,174	27,5
G.216	0,321	24,8
G.219	0,055	no signal detected
G.220	1,051	24,8
G.221	0,214	28,6
G.222	0,435	27,4
G.223	1,213	23,9
G.224	0,344	27,6
G.225	0,268	27,7
G.226	0,411	23,5
G.227	0,295	23,9
G.303	0,769	24,1
G.304	0,134	24,5
G.400	0,204	27,6
G.404	0,325	27,6

G.408	3,713	27,1

5. Slaughtered like animals. Revealing the atrocities committed by the Nazis on captives at Treblinka I by skeletal trauma analysis.

5.1. Abstract:

The infamous KL Treblinka camp was one of numerous extermination camps throughout Poland, where Germans carried out mass killings of Jews. The camp was divided into two parts, AL Treblinka I, a forced labor camp, and KL Treblinka II, the site of the extermination camp. Treblinka I held captives of various origins and ethnic backgrounds who were serving their sentences by working in a pre-existing gravel pit. Many of those prisoners died in the camp and it was believed that the principle causes of their death were attributed to the horrific sanitary conditions in the camp as well as the strenuous hard work of daily life.

In 2019, archaeologists uncovered a clandestine mass burial pit that contained commingled human skeleton remains at the Execution Site of the former Treblinka I camp. It was estimated that there were a minimum of forty-nine people in the pit. Within months an anthropologist performed biological profile assessments and detailed trauma analysis on the recovered skeletal parts. Our main goal was to study perimortem trauma patterns to infer the cause and manner of death of the victims. We hypothesized that the victims did not die solely because of the camps' conditions but were brutally slaughtered by the camp guards. Our results were later compared with the survivors' written testimonies.

As a result of our research we were able to show that the Treblinka I captives' death was extremely brutal, and that the methods of killing were varied. This led us to conclude that there were multiple assailants who were involved in the killing spree. All of our results were consistent with the written witness testimonies, which makes the skeletal material hard proof of the crimes committed by the Nazis on their civilian prisoners during the war.

5.2. Introduction:

In any murder case, the victim's body is regarded as the hard evidence of a crime [103]. Without it, the case could only be circumstantial and it is usually very difficult to prosecute the perpetrators in question [104]. With this in mind, Heinrich Himmler ordered the bodies of the dead to be incinerated and commingled, including most of the corpses that were previously buried in mass burial pits [105] in all the concentration and extermination camps in Europe. As a result, the only existing proof of mass killings are the survivors' testimonies that were written shortly after the end of the war.

Approximately six kilometers away from Treblinka train station in Sokołów County, Poland lay a gravel pit which was controlled by the German forces from September 1939 [21]. The gravel was an important resource for implementing the so-called "Otto Program", a plan for building strategic roads to attack the Soviet Union [106]. The biggest obstacles Germans had to overcome was the workers' shortage. In order to solve this, they constructed a forced labor camp, Treblinka I, where they imprisoned mainly people from the nearby villages and forced them to work in the pit.

By 1941, the first prisoners arrived there to serve their sentences. In the first year of the camp's existence there was no division of Jewish prisoners from Polish ones [21]. After the construction of the extermination camp Treblinka II, some of the Jewish captives were still sent to the labor part of the camp (which in German announcement of 16. December 1941 is defined as *Arbeitslager Treblinka*) and their physical work conditions served as means of annihilation. The daily strenuous physical work combined with low nutrition rates, diseases and beatings from the camp guards contributed to the early demise of a significant number of prisoners. In contrast to other forced labor camps, such as KL Auschwitz, there are few survivors of the imprisonment in Treblinka camps [107]. Therefore, the testimonies on the causes and manners of death of the inmates are vague. The witness' statements report on the camp guards' cruelty and also state of the variety of killing methods. The weapons used for killing, according to the Treblinka survivors, include a bat, a plank, a bayonet, an axe, a hammer, a mallet, a saber, a gun and many others [21], [108], [109]. However, those statements were never supported by any other physical evidence.

One of the first examinations of Treblinka camps was undertaken by the Soviets and Polish people on 24th August 1944. Then it was revealed that the Germans buried their victims in various locations in the camps. Around fifty-eight burial pits were discovered, measuring 10x5 meters and 2-2.5 meters deep. Three of those graves were dug open on a total surface of 15x5 meters. 305 corpses were exhumed. Twenty-five of them were women. The bodies were interred only 50 centimeters from the top of the ground. It was calculated that in the graves around 10.000 to 12.000 people rested. Fourteen bodies were subjected to an autopsy. The medical examination showed that the victims' skulls were pierced after the blow of an axe and other similar objects (found in the copy of the deed dated on 24th August 1944 translated from Russian into Polish and stored in the Institute of National Remembrance archives, accessed on 15th February 2022; Central Commission for the Investigation of German Crimes in Poland [110]).

Since then, no other detailed research into Treblinka camps has been done. In the 1960s, a Museum of Struggle and Martyrdom was established to protect the victims' memory. Only in 2007, archaeological and historical research on the Treblinka camps began by scientists from Staffordshire University in the UK. The researchers obtained permission to study the site with the use of little invasive methodology. They were not allowed to exhume the bodies from the graves. Combining LiDAR survey, walkover survey and archival map research, six potential mass burial pits were detected in the area of the Execution Site near the former labor camp [18]. Three of those sites were excavated using minimally invasive techniques [111].

In 2019, a previously unknown burial pit was discovered at the bus station car park which belongs to Treblinka I camp. The pit contained the commingled remains of nearly fifty people. Neither their identities nor their causes and manners of death were known. Following DVI standards [41], the interdisciplinary team was engaged in the process of the remains recovery and personal identification. The team consisted of experts in forensic archaeology, forensic anthropology, forensic medicine and forensic genetics.

We assumed that the victims were the Treblinka I captives who were killed by the camp guards. Our aim was to analyze the recovered skeletal remains with the main focus on perimortem trauma study. We hypothesized that the trauma pattern would allow to infer the most prevalent killing method applied by the guards and the relation of the assailants towards the victims. By comparing our results with the survivors' testimonies we hoped to identify specific camp guards responsible for the crimes that had been committed, which in turn could help in legal actions, to bring closure to the victims' families. Our secondary goal was to explain the state in which the remains were found. The archaeological evidence point to secondary burial, but it is unknown why the skeletons were commingled nor who was responsible for the commingling.

5.3. Material:

When the Germans retreated from Treblinka, they tried to hide all the evidence of their atrocities, so most of the buildings were destroyed [112] and the victims' bodies were buried in undisclosed locations. No structures of crematoria and other buildings from extermination camp survived. In the part of labor camp, only building foundation survived. Beginning from 1944, some of the mass graves were found, together with individual burials [113]. Already then, it was noticed that the bodies from extermination camp were disposed in various manner. Some were interred in mass burial pits, some were cremated and buried, others were scattered on the ground after cremation. Contradictory, the bodies from labor camp were not cremated, but they were buried in mass burial pits. Those observations were taken into account by Staffordshire scientists when they prepared the survey [111], [114]. The place where most of the graves were revealed was named the Execution Site in the 1960s [22]. It is located to the south of the gravel pit and the labor camp. There, were shot the wounded and exhausted, those sentenced to death for camp offenses, as well as Poles brought from Warsaw and Sokołów Podlaski. On March 2nd 1942, around a hundred people from the prison in Pawiak Szucha alley were brought here and shot to death. Executions of Jews from Warsaw ghetto and Romanis were also carried out here. Possibly the Italian officers and soldiers died here as well [115].

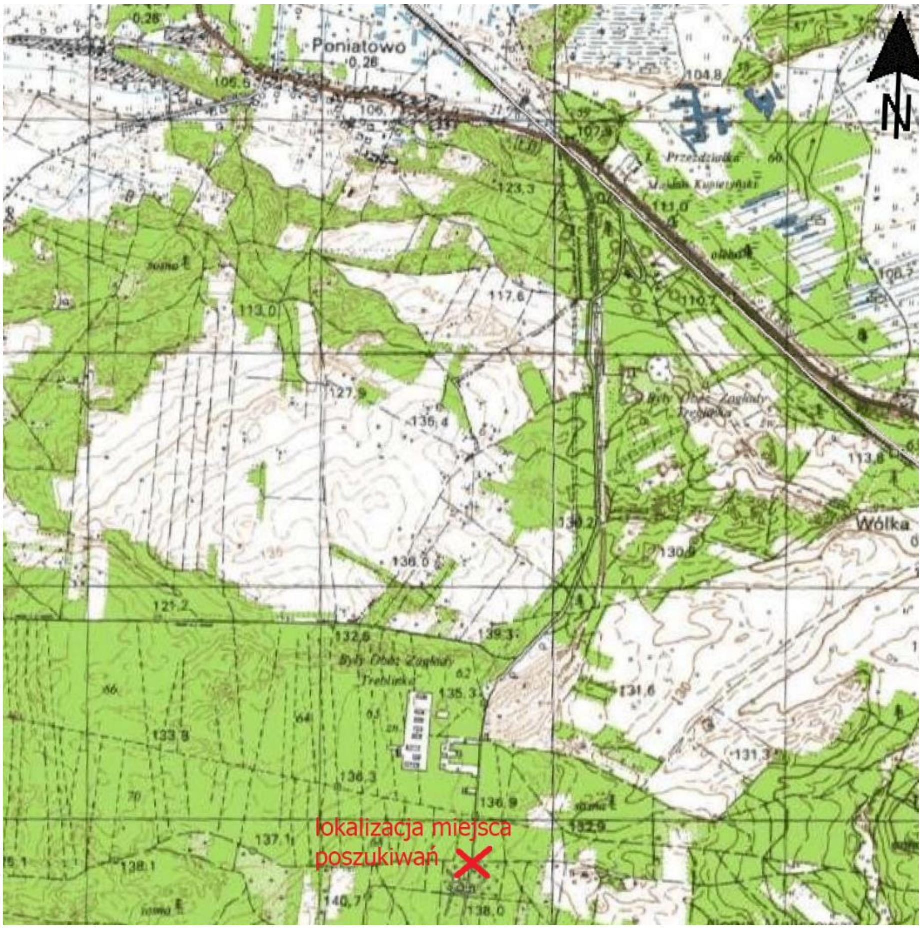

Figure 2. The map showing the search place. Red "X" marking location of the search (www.geoportal.pl).

In November 2019, under the carpark of Treblinka Museum, the area of the Execution Site, human bones were revealed [22], [116] in a burial pit sized 4,5x3,4 m. The skeletal remains were resting only 15cm from the top of the ground, so many skeletal elements were highly fragmented. Upon the decision of the National Institute of Remembrance prosecutor, the pit containing the remains was excavated with the use of forensic archaeology methods. The skeletons were already extremely commingled in the grave, none were laid in the anatomical position. Each skeletal element was cleaned from the dirt on-site, tagged and wrapped. The material was sent to the Forensic Genetics Department of Pomeranian Medical University in Szczecin for detailed anthropological and genetic analysis that would lead to personal identification and cause and manner of death determination.

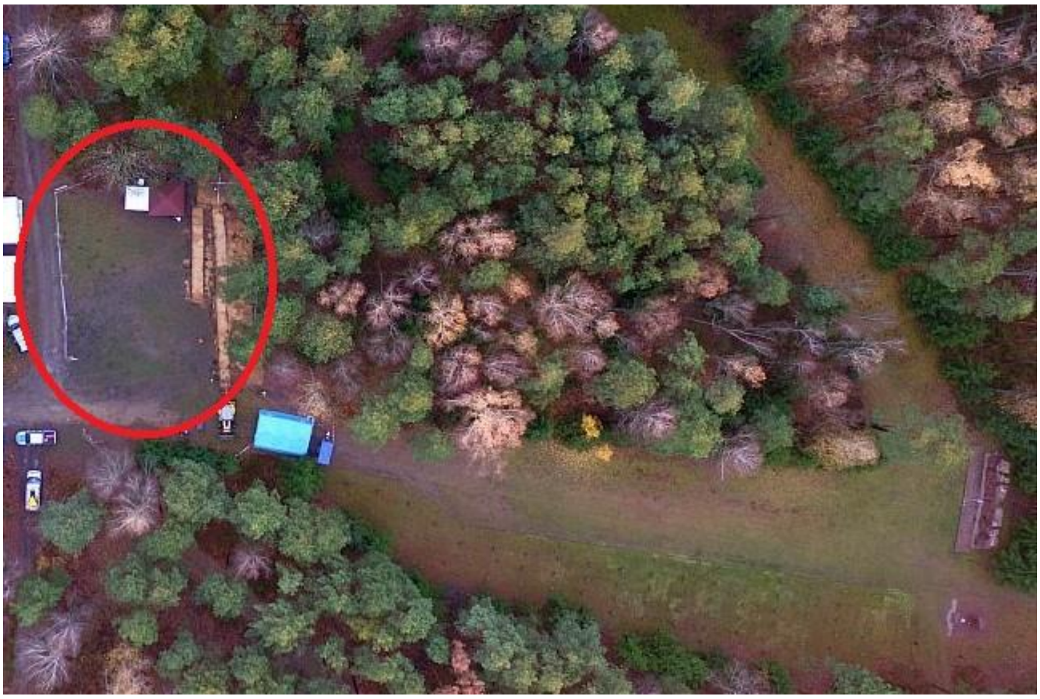

Figure 3. Location of site 1- eastern orientation (photo credit A. Ossowski).

5.4. Methods:

5.4.1. Archaeological methodology used for localization and exhumation of the graves:

For the reason of coming modernization and earthworks in the forest car park by Treblinka Museum, the archaeological survey began there. The main goal of the archaeological survey was the search for clandestine burials of victims who died in the forced labor camp, as well as other victims brought here from Warsaw for execution. The search took place in the vicinity of the Execution Site, in the forest parking lot (site 1), and to the west of it, behind the road leading from the camp to the monument commemorating the camp victims (site 2). Two sites were designated for archaeological survey. Site number 1 encompassed the area of 930 m^2, and site number 2 was the area of 1300 m^2. The exploration area of site 1 was divided into sectors. Firstly, the surface of the site was examined with Ground Penetrating Radar to detect any anomalies that would indicate the existence of the graves below the surface [117]. In previous research campaigns (2016-2018) the analysis included extended spatial data, geophysical measurements and excavation work. These results were used to select research areas and conduct geophysical and excavation survey in 2019. [117] Metal detectors were also used to find and collect relevant artefacts (fig. 3, 6, 7).

Figure 3. A Jewish Ghetto Police badge found on the ground of the studied area.

Next the surveys were marked and with the use of a digger with a slope bucket small layers of humus were removed together with the alluvial level of soil up to the level of the bedrock. These works were carried out under the archaeologists constant supervision. Once the skeletal remains were within reach, the exploration was combined with the bones simultaneous exhumation (fig. 4, 5). The tools used in that stage were made of plastic to prevent any skeletal destruction and to preserve any possible crime evidence that could be relevant in the course of the investigation.

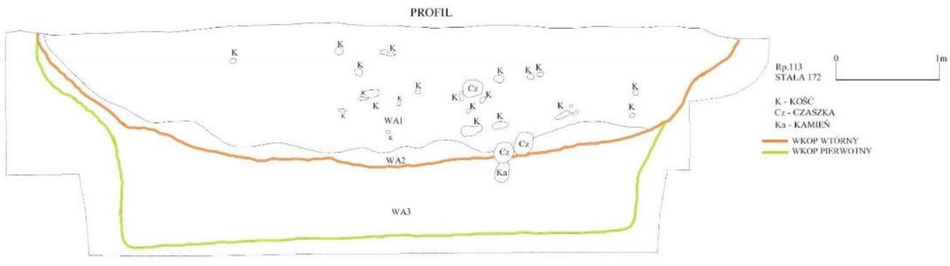

Figure 4. Western profile of mass burial pit, partly reconstructed based on the archaeological documentation (figure credit M. Wołyńska). K- bone; Cz- skull; Ka- stone WA1- layer 1; WA2- layer 2; WA3- layer 3.

The object was explored in quarters documenting profiles until the layer was outlined, which was interpreted as the original filling of the burial pit. It was decided that it will be fully unveiled in the plan. After completing the documentation and a small survey, the layer was explored in its entirety, which was also combined with the exhumation of human bones deposited in it without anatomical arrangement. Due to the clear outline of the excavation and the course of the layers, the method of exploration with natural layers was used and the exhumed remains were assigned to them. The skeletal remains were secured with bubble wrap and put in paper bags signed with the date, site number, and layer number. Finally, the packed material was transferred to an anthropologist for osteological analysis. Soil samples were taken from layer 1 for laboratory testing for the presence of explosives. For comparison purposes, soil samples from outside the grave were also taken.

During archaeological surveys in 2019 another group of graves (site 2) was discovered and uncovered at a distance of a few meters in west direction from the site 1. Archaeological survey of site 2 showed that this group of graves was diametrically different from the burial pit of site 1. Seven graves at site 2 were singular graves arranged in a regular row with all bodies placed in coffins with some grave goods suggest a different status of buried bodies. It is possible that the singular burials of site 2 belonged to the camp guards, so called the Watchmen (*SS- Wachmannschaften*). The details of site 2 and results of analysis will be subject of a separate paper.

Figure 5. Western profile of the mass grave pit explored to the level of the original filling. NE view.

5.4.2. Anthropological methodology:

As the bones were in a very fragmented state, it was necessary to reassemble fractured elements before the analysis began. Every element was labeled with a different tag, measured and described on a specially created spreadsheet. Elements were segregated in accordance with the body side and for each element the possible components of the biological profile were assessed. The biological sex was estimated by the use of morphological [50] and metric [51] methods on the coxal bones. On femoral bones, metric methods were applied [52], [53]. On the skulls a morphological trait assessment method was used [54]. The biological age-at-death was estimated on the basis of bone length measurements in subadults [118], and skeletal ossification stage [46]. In adults, a method based on morphological features of pubic symphysis was applied [47]. The stature was estimated with the use of a metric method based on femoral bone measurements and a regression formula with regard to the estimated biological sex and biogeographical origin [57]. Ancestry was evaluated using the skulls' measurements and the software Ancestrees [55] and Cranid [119] and a non-metric trait method [56].

Every pathological condition and traumatic lesion was photographed and described in detail on a created spreadsheet. The description included the location of a lesion on a bone, the type of lesion and its dimensions. The pathological lesions included non-specific stress indicators, such as *Cribra Orbitalia, Cribra Cranii, Cribra Femori, Linear* and *Punctual Enamel Hypoplasia*. Those traits as well as metabolic disorders could reflect the general health status of a person.

Bone fracture descriptions include type of fracture, mechanism, time of occurrence and possible direction of the impact. In ballistic trauma, the entry and the exit wound location, diameter and probable bullet trajectory were included in the analysis. Additionally, in every trauma case, a possible weapon responsible for the traumatic mark was inferred. When referring to the timing of trauma, the term perimortem was applied, meaning trauma that happened on fresh, hydrated bone [58].

To resolve the issue of commingling, we tried to follow the methodology described by Adams [45]. The spatial location of each excavated skeletal element was marked during the exhumation process on tags and later on the spreadsheet, in the hope of possible element association by the proximity of the next skeletal part in the joint [120]. Moreover, each skeletal element was measured [121] and in the cases of subadult skeletons, the bones could be matched on the basis of the assessed biological age-at-death [122]. Other methods include taphonomic changes comparisons of the bone periosteum [11].

The trauma frequency indicator was calculated from the number of cranial impacts and the number of cranial elements that were preserved. The small sample prevented us from obtaining any significant results after applying statistical tests. Therefore, the results were analyzed using empirical and descriptive approaches as opposed to statistical analysis.

5.4.3. Genetic methods used to verify anthropological sex estimates and mt haplogroup determination:

The teeth samples were taken for DNA analysis, using modern forensic DNA methodology to obtain genetic profiles that would serve for personal identification once the reference material is provided.

The teeth were cleaned mechanically and chemically, and ground in a cryogenic mill. DNA was extracted and purified from the prepared bone powder with PrepFiler ™ BTA Forensic DNA Extraction Kit (Thermo Fisher Scientific) according to the manufacturer's protocol. Quantitation of DNA extracts using the Quantifiler™ Trio DNA Quantification Kit (Thermo Fisher Scientific) on the 7500 Real-Time PCR Instrument (Thermo Fisher Scientific). STR markers were amplified using a commercially available kit –GlobalFiler (Applied Biosystems), which includes three types of markers that allow for genetic sex determination: a fragment of the amelogenin coding gene, located both on the X and the Y chromosome, with a different allele length for each variant, and two markers located on the Y chromosome exclusively: an insertion/deletion marker and an STR marker. For the analysis of Y-STR markers, the Y-Filer™ Plus PCR Amplification Kit (Applied Biosystems) was used, and the kit can amplify 25 Y-STR loci.

Positive and negative controls were prepared for each amplification to assess the performance and purity of the amplification step. The positive control contained the reaction mixture and DNA control, and the negative control contained the reaction mixture and nuclease-free water.

Detection of PCR products was performed on a 3500 Genetic Analyzer sequencer. The results were analyzed using GeneMapper® ID-X Software v1.6. Haplogroup estimation from consensus profiles was performed using the EMPOP database [61] and the HaploGrep software [62]

Mitochondrial DNA sequences have been determined for the HV1 and HV2 hypervariable regions. The sequences of the amplification primers used were in accordance with the literature [60] for primer pairs: 15971 and 16410 for HVI and L15 and R429 for HVII. The hypervariable regions were amplified in two separate PCR reactions using the HotStar Taq Master Mix Kit.

In addition, as no reference material from the families of the victims was obtained to this day, an analysis of kinship between the exhumed remains was performed on the Familias 3 software (http://familias.no/) [123], [124]. The Familias program, developed by Petter Mostad and Thore Egeland in cooperation with the Norwegian Computing Center and the Institute of Forensic Medicine in Oslo, is used to calculate probabilities of complex kinships. Moreover, it includes a DVI module, in which two databases are created: the victims' database and the reference families' database. This allows for searching for the highest likelihood ratio (LR) of a victim to be related to any reference family in the database versus not being related to them, as well as to establish the LR for a presence of kinships between individual victims themselves, versus no kinship between them. Because in the mass grave only males were found, when analyzing kinship in the Familias program, three kinship models were assumed:

1. parent-child
2. sibling
3. cousin

5.5. Results:

5.5.1. Archaeological results.

In survey no. 1, in its eastern part, during topsoil removal, human remains were uncovered, without anatomical arrangement, lying directly under the layer of turf. In order to fully reveal the outline of the excavation, survey no. 1 was extended and widened at this point. An oval-shaped pit, oriented along the north-south axis, measuring 6.5 x 3.4 m was uncovered. The fully explored pit was 205 cm deep. The analysis of the course of layers and the edges of the excavation, clearly visible thanks to the documented profiles, confirmed that we were dealing with two phases of the functioning of the burial pit: the primary and the secondary dig.

The primary dig consists of bones deposited without a visible anatomical layout. The bones were placed without any plan, at various angles, on different levels. They did not form a compact structure, but were dispersed in a layer of light brown sand and gravel, which was the filling of the grave (layer 3). These were skulls, long bones, short bones and others. The width of the pit narrowed in a basin to about half its depth, creating a step from which the walls went vertically down. The minimum length of the pit was about 6 meters, and the minimum width was about 1.5 meters. The maximum depth of the pit was around 200 cm, but the thickness of the layer that was not disturbed by the secondary dig was around 70 cm.

The secondary dig was oval in shape, measuring 6.5 x 3.4 meters. Its cross-section, 135 cm deep, was basin-shaped, possibly reproducing the original course of the burial pit, reaching approximately two-thirds of its depth. The backfill of the trench was layer no. 1, 130 cm thick, consisting of brown sand and medium and coarse gravel with human bones, and layer no. 2, up to 20 cm thick, consisting of sand with a significant content of dark brown humus. In contrast to the original fill (layer 3), the sand and gravel of layer 1 were more saturated with organics, resulting in a more intense brown color. In the case of layer 2, considering the significant amount of humus, it could have been formed, for example, by winding a significant amount of leaves or as a result of the formation of forest litter.

In addition to bones, single items were found in the backfill, mainly fragments of fabrics and leather, most likely the remains of clothes and footwear, items of clothing such as buttons, belt buckles, but also a Polish coin from 1936 (fig. 6). The pit also contained elements of ammunition, such as shells and projectiles (fig. 7). Among the artefacts recovered with the use of metal detectors, a badge of the Jewish ghetto police in Falenica was found (fig. 3).

Figure 6. Polish coin from 1936 found in the explored burial pit.

Figure 7. A bullet shell found in the Station 1.

In the place where GPR surveys indicated anomalies in the ground, stones were registered, which are natural inclusions in the sand and gravel bedrock.

The archaeological results show that the burial pit was not of a regular shape. One hypothesis surmised by archaeologists was that a deep hole could have been created after the detonation of explosive materials. The samples that were collected from the pit for trace element analysis suggested that no explosives had been detected or used. The layout of the skeletal remains in the pit suggested that, without doubt, the grave had been disturbed or the pit had not been the primary burial place for the remains.

5.5.2. Anthropological results.

The recovered material entailed more than 8 600 skeletal fragments. The minimum number of individuals (MNI), which was estimated from the preserved skull bones, right ulna and right coxal bones, was forty-nine people. The number of other preserved elements (fig. 8) did not deter far from the estimated MNI. The poorest preserved were patellas (forty-one right and forty left bones) and sternum (forty bones). It was impossible to assign each element to a particular skeleton within the given time frame for the analysis. We may only infer the shortest skeletal elements belong to one person and the longest elements to the tallest person. Based on the collected data, it is possible to match more skeletal elements with particular individuals in future studies.

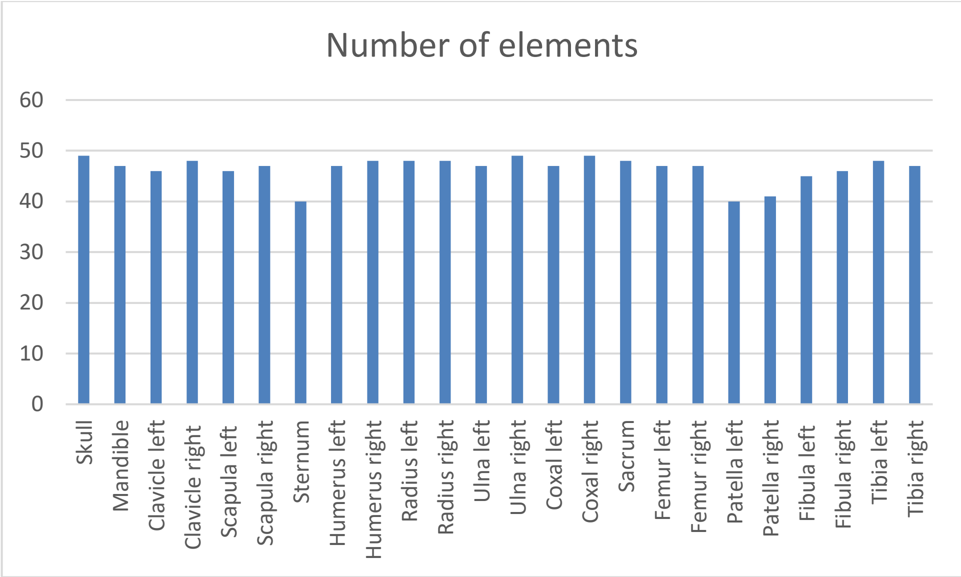

Figure 8. Number of preserved skeletal elements.

From the entirety of studied skeletal material, the evaluated biological profile shows that the biological sex of all individuals, that were successfully assessed, was male. The estimated biological age in the studied population spans from around ten-years-old to over sixty-years-old at the time of death. The stature ranges from 145cm to 180cm (+/- 3,27cm). It was possible to perform ancestry estimations only for thirty-three skulls. Seventeen of them were estimated as most similar to European, four as Northeast-African, and three as South-Asian. For nine skulls, the analysis executed by two chosen software (*Ancestrees* and *Cranid*) gave contradictory results.

The analysis performed on the skulls (table 1.) showed that the minimum number of individuals was forty-nine. The biological sex estimated from the skulls was male and possible male for thirty four people (69%), one skull (2%) displayed a few morphological female characteristics, and unknown sex for fourteen skulls (29%). The highest number of individuals were classified in the age category 18-30; thirty-three people (67%); thirteen skulls (27%) had assessed the biological age as 31-55; one skull (2%) was assessed to be over 56 at the time of death. For two skulls (4%) it was impossible to estimate any component of the biological profile.

Table 1. Age and sex distribution estimates from skulls.

AGE GROUP	MALES		POSSIBLE MALES		POSSIBLE FEMALES		UNKNOWN SEX		TOTAL	
	N	%	N	%	N	%	N	%	N	%
18-30	13	26.53	9	18.37	1	2.04	10	20.41	**33**	**67.35**
31-55	8	16.33	3	6.12	0	0.00	2	4.08	**13**	**26.53**
56+	1	2.04	0	0.00	0	0.00	0	0.00	**1**	**2.04**

UNKNOWN AGE	0	0.00	0	0.00	0	0.00	2	4.08	**2**	**4.08**
TOTAL	**22**	**44.90**	**12**	**24.49**	**1**	**2.04**	**14**	**28.57**	**49**	**100**

a. Trauma analysis results and skeletal pathology.

Fifteen skulls were preserved without any visible signs of injuries. The perimortem trauma was observed (fig. 9) on thirty-four skulls (69%), fifteen mandibles (32%), and on postcranial bones on three sacral bones (6%), one left (2%) and four right (8%) ulnas, two left (4%) and two right (4%) coxal bones, one left (2%) and one right (2%) tibia, two left (4%) humerus, one left (2%) fibula, three left (6%) and one right (2%) femur, six left (13%) and six right (13%) scapulas, one right (2%) clavicle, vertebra, ribs and metacarpals. The types of injuries include blunt force trauma, gunshot trauma and sharp force trauma.

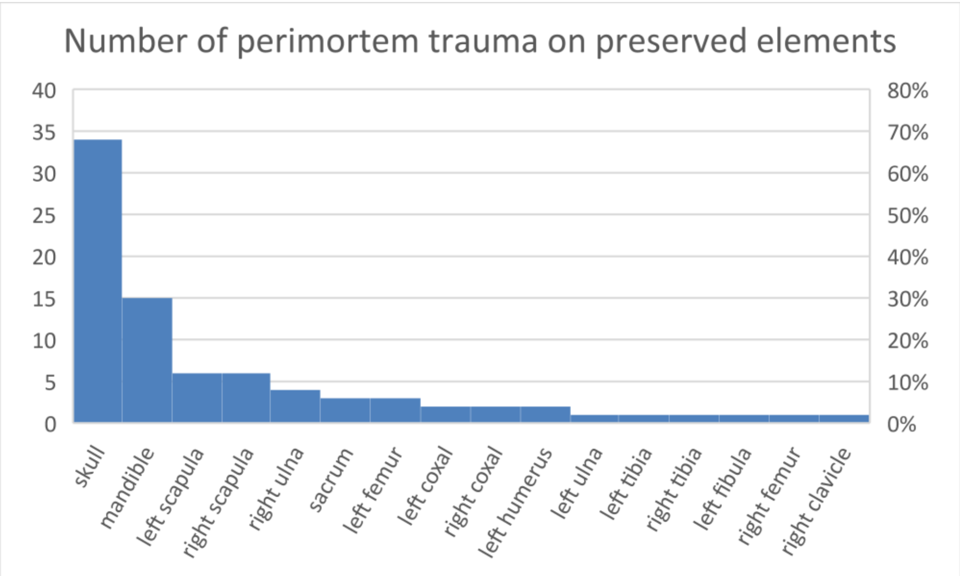

Figure 9. Number of skeletal elements with perimortem trauma marks.

In six skulls (12%), sharp force trauma was detected, four skulls (8%) manifested ballistic trauma, twenty-nine skulls (59%) showed blunt force trauma. Three skulls (6%) have lesions of combined blunt force trauma and ballistic injuries. Two skulls (4%) illustrate a combination of injuries inflicted by a blunt and a sharp instrument. Twelve skulls (24%) demonstrate multiple blunt force trauma impacts (from minimum two impacts to minimum five impact points detected). Among the observed perimortem lesions, on twenty-two skulls (45%), trauma could have been lethal. The sharp force injuries on four skulls were located near the foramen magnum rim and occipital condyles, but didn't affect mastoid processes. That kind of trauma could have led to decapitation and would most certainly cause severe damage to *Medulla oblongata*. In two cases, sharp force trauma was detected on the maxilla, specifically in the nasal area (piriform aperture).

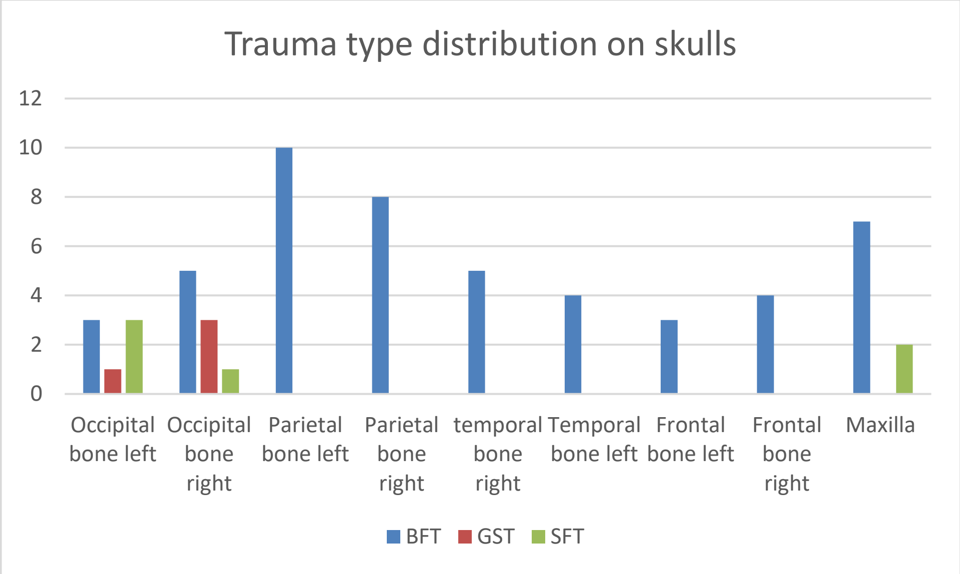

Figure 10. Distribution of types of trauma on cranial elements.

The highest number of blunt force trauma impacts were localized on parietal bones left and right (fig. 10), usually at the top of the head, above the so-called Hat Brim Line (HBL). Many lesions found on parietal bones were of concentric and radiating shapes (fig. 11). Those traumatic marks that were noticed on occipital bones were mostly linear fractures. The gunshot trauma trajectories went in all cases from the occipital bone to the frontal bone. The entry wound diameter is around 7mm, which indicates a small caliber bullet.

Figure 11. Skull nr TI_1069 with perimortem depressed fracture.

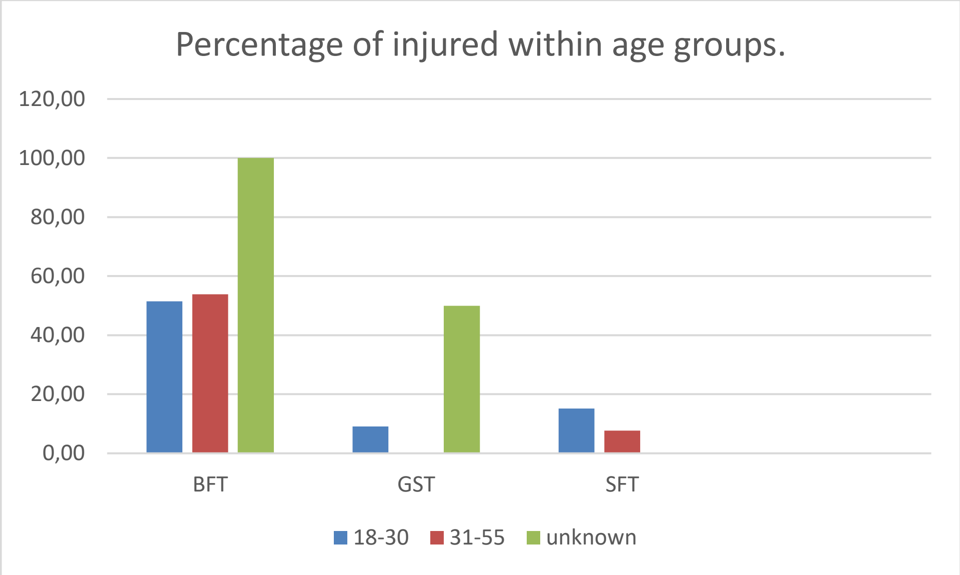

Figure 12. Percentage of injured people with regard to age category and trauma type.

Within the youngest age category of the victims (18-30), twenty-seven blunt force trauma blows were observed on seventeen skulls, three gunshot injuries on three skulls, and five skulls displayed sharp force (fig. 12) trauma. In the age category 31-55, there were eighteen blunt force trauma impacts on seven skulls, and one sharp force injury on one skull. There was no perimortem trauma noticed on the skulls of victims at the age category 56+. There are three blunt force trauma impacts on two skulls and one gunshot trauma on one skull of people of unknown age-at-death. In the middle age-at-death category (31-55), the frequency of blunt force trauma injuries per person is higher than in the youngest age category, but there are no gunshot injuries detected in that age category (fig. 13). The blunt force trauma types- concentric and radiating, are more prevalent in the youngest age categories than in the middle-aged one.

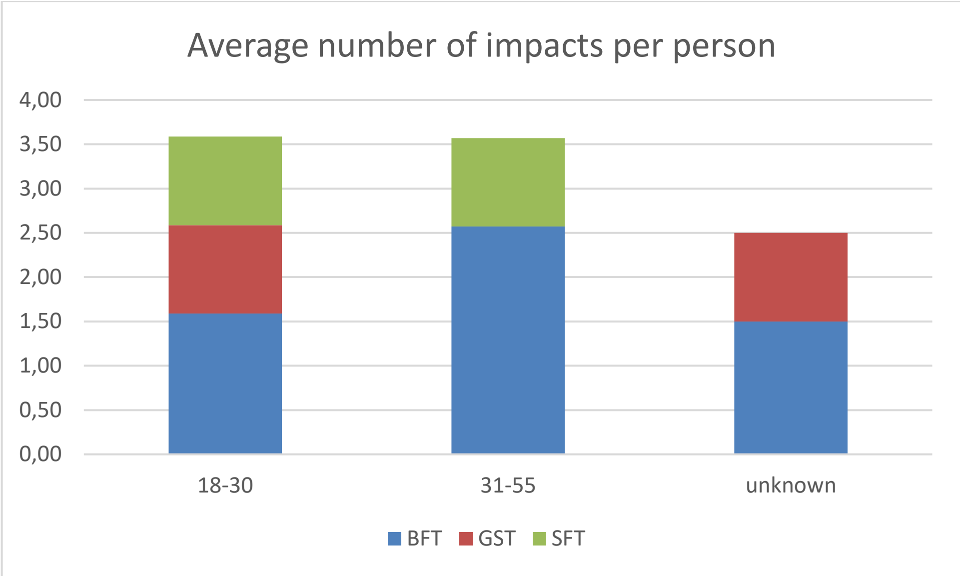

Figure 13. The average impact frequency of different trauma type per person within estimated age categories.

In postcranial elements, the majority of trauma mechanisms were spiral, transverse and linear, most likely caused by contact with a blunt object. On one left femur there is an entry hole from a gunshot injury, without any exit hole. Apart from the elements listed above, the perimortem fractures are also visible on cervical and thoracic vertebra, metacarpals and ribs. The ulna fractures could result from a parry mechanism, but other mechanisms (such as a fall) are also possible. The metacarpals' fractures could result, among many other possibilities, from a physical attack on someone. On the cervical vertebra there are visible sharp force trauma marks and blunt force trauma.

On two skulls, *Cribra Orbitalia* was found; on one skull was *Cribra Cranii*. In postcranial elements on two right and one left femurs *Cribra Femori* was shown. On the teeth of thirteen mandibles linear enamel hypoplasia (LEH) was found, on two mandibles punctual enamel hypoplasia (PEH) was present. Bones of a minimum two people show signs of pathological bowing, which could be a sign of metabolic disease. The skeletal elements affected by that condition are femurs, tibias, fibulas, humerus, ulnas and radius, all belonging to adults. On vertebrae and sacrum bones are rather advances lytic lesions, which could indicate a long-lasting disease such as brucellosis, tuberculosis or some other parasitic disease, such as malaria.

5.5.3. Genetic results.

Out of the teeth collected from 46 individual skulls, only 25 yielded results that allowed for the genetic sex estimation. It was possible to obtain genetic sex results for 25 skulls. All of them were males. The poor state of preservation of the biological material, which was observed in the results of DNA quantity and quality assessment by Quantifiler TRIO, was also clearly visible in the results of fragment analysis – partial profiles or no profiles were obtained for the majority of victims.

The haplogroup as a result of the analysis of hypervariable regions of mitochondrial DNA (HV1, HV2) was obtained for 19 individuals. The genetic mtDNA haplogroup estimates are: N1b1b, K, W, J1c7, HV, W3b1, K1a, K1a1b1a, H3p, R0, V7a, K1a1b1a, H2a2a. The obtained mtDNA haplogroups were estimated in the EMPOP database and the HaploGrep program. The results obtained on both software were identical. Those estimates are in concordance with anthropological ancestry estimations.

For none of the assumed kinship hypotheses (father-son, siblings, cousins), the relationship was confirmed. This could, however, have resulted from the state of preservation of the biological material. All DNA profiles obtained in this study, including partial ones showing signs of strong degradation, were used for the biostatistical analysis. The possibility of the occurrence of drop-out (true alleles not present in a profile) and drop-in (false alleles present in the profile) phenomena, which hinder the result of kinship analysis, can be quite high in such a low-template, highly degraded material [125]. Thus, the results do not allow us to unequivocally state that no related victims were exhumed from the mass grave in the former Treblinka I penal labor camp.

5.6. Discussion:

The skeletal analysis of victims killed in World War II concentration camps is very rare, not only because of cultural obstacles regarding the exhumation of the victims' bodies [18], but also because many of those bodies were destroyed (burnt and pulverized) during the war to obscure the magnitude of the crimes committed by invaders on civilians (Sonderaktion 1005; [126]). As a result, many of the genocide survivors, friends and families of the victims never discovered the truth about the fate of their loved ones. Some of the victim's families are still alive, waiting for any news regarding their kin [39], and that is one of many reasons why the identification process of people killed in concentration camps during the war should be continued. The forensic skeletal analyses includes not only the basic biological profile estimated from the preserved victim's skeleton, but also contains medico-legal aspects of perimortem trauma analysis and cause and manner of death inference which can provide clues on how the victim died [9].

The main goal of our research was to analyze the perimortem trauma pattern on the recovered skeletal elements from the burial pit on the terrains of the former German forced labor camp KL Treblinka I. The trauma study results compared with the survivors' testimonies could help in the victims identification process and could possibly reveal the perpetrators' identity by connecting trauma patterns with the specific camp guards killing preferences.

The studied skeletal material was found in an already commingled state in one burial pit of irregular dimensions. The exact reasons for commingling are unknown, but researchers pose few hypotheses to explain that state. From May 1942 until 1944, upon the orders of Paul Blobel, following the Sonderaktion 1005, the remains of the killed people were exhumed, commingled and reburied or additionally burned and reburied [127] to hide the evidence of crimes committed on civilians in concentration camps. Historical sources mention that after the camp's liberation the local people from the villages surrounding Treblinka dug up the bodies in search of treasure (gold, jewels, money etc.; [21], [22], [128], [129]). Those actions surely caused disturbances in the body's organization in the graves as well as relocation of certain bodily elements, causing commingling. Another possibility is that the culprit for commingling are the Soviets, who used explosive materials in the graves to facilitate their search for valuables on the victims' bodies [130]. Following that trail, the researchers collected samples of the soil and sent it for trace element analysis, hoping to find traces of explosive materials. That theory would also explain the sill-like shape of the burial pit. However, the results of the analysis show no explosive material elements in the pit.

The interpretation of perimortem trauma patterns from the skeletal remains can provide only partial information on the total injuries inflicted on a victim. The majority of the torso injuries, regardless of the type: blunt force trauma, gunshot trauma or sharp force trauma, are limited to the soft tissues leaving no traces on the bones [131]. However, there are certain skeletal fracture patterns indicative of interpersonal violence, such as the cranial factures, facial bone trauma, zygomatic, maxilla mandible, nasal, orbital rims etc. [132] and in postcranial bone fractures of the ribs, metacarpals [133] and forearm bones, so called parry fractures [134]. The overall trauma pattern visible on cranial and postcranial bones in our studied sample is consistent with the countless published bioarchaeological evidence of interpersonal violence.

In our studied material, we observed blunt force trauma marks on the cranial vault bones usually in the form of depressed concentric and radiating fractures. Those kinds of fractures frequently occur after a blow with a relatively small surfaced object to the head that rests on a solid surface such as a wooden log or a stone [76], [135] as opposed to blows to a free-moving head, which will form linear or incomplete depressed fracture shapes. From many matching published testimonies of the KL Treblinka survivors: Zdzisław Makowski, Marian Kobyliński, Jan Kiełko, Antoni Tomczuk, we know that on the terrain of the camp there was a *Holzplatz,* a place where some of the woodworks were prepared. In that place, Untersturmfuhrer Franz Schwarz and Gruppenwachman Franz Swidersky performed executions on prisoners by hitting them on the head with a mallet in a body position where the head of the victim was put on a wooden log or a rock [21], [22]. Those testimonies correspond with our study results of the victims' fracture pattern.

On several skulls, sharp force injuries were detected, some were found on the maxilla and nasal bones and others were in the area of the foramen magnum or cervical vertebra. Perimortem sharp force trauma located on the skull bones is usually encountered in a manner of death by homicide [136]. Stab wounds that include the spinal cord are rarely reported in the literature. For now, the biggest data on that kind of injury was gathered by Peacock et al. [137] on South African samples. He accounts in his study that the most common weapon for stabbing through the spinal cord is a knife or an axe, but sickles, scissors and other sharp instruments are also used. Similar lesions can be found on skeletal remains of victims of decapitation. The most affected skeletal regions in decapitation cases are cervical vertebra, occipital condyles and foramen magnum rim [138]–[140]. It has been described in various publications that one of the various Nazi killing methods they used on their prisoners was beheading [141]–[143]. They even used a guillotine for that in other locations, such as Plotzensee Prison [144].

The sharp force trauma marks visible on the maxilla and nasal bones could be inflicted most probably by a knife, a sword or a saber. From the survivors' testimonies we learn that one of the camp guards had a saber which he used to mutilate the prisoners by cutting off their ears and noses and women's breasts [145]. The camp guards were equipped with bayonets and knives that could easily create most of the aforementioned sharp force trauma lesions [21]. From these testimonies, we also know that in most cases the killings were done by a weapon of opportunity, for example a bat, a rock or a pickaxe. A pickaxe could match the bone marks found on some occipital bones.

AL Treblinka I was a forced labor camp set up to recover the precious resource for a concrete road construction, a gravel. The work in the gravel pit was extremely hard, many prisoners died of exhaustion every day of the camp's existence. However, the amount of perimortem trauma on the recovered skeletal material suggests that the majority of people buried in the exhumed burial pit did not die of natural causes but were instead murdered. One of the possible reasons why the perpetrators would kill the essential workers, could be the weak physical state of the prisoners. Our study shows that on several skeletal elements were visible non-specific stress indicators, such as *Linear* and *Punctual Enamel Hypoplasia, Cribra Cranii, Cribra Femori, Cribra Orbitalia*. Dental *Enamel Hypoplasia* (linear or punctual) usually forms early in life and is prevalent throughout adulthood. The etiology of the defect formation can vary. For example, nutritional deficiencies, congenital abnormalities, disease, and even trauma [146]. Therefore, the condition is categorized as a non-specific stress marker. A multiple published research exhibits that stressors acquired in early life influence the adult infection-related immunity and in consequence individual's life span [147]–[150]. On the other hand, the non-specific stress indicators that manifest themselves on bones as porotic lesions, *Cribra*, can occur in any stage of life, even several months before the victim's death. The etiology of the condition is not specified, usually it is associated with iron deficiencies [131]. All these lesions, *Enamel Hypoplasias* and *Cribras,* could be a signal of the frail physical conditions [151], [152] of prisoners, which in turn would not benefit the labor demands of the camp's commandant.

The commingling of the skeletons certainly hinders the personal identification process. It is estimated that around 800000 people died in both Treblinka camps. The provenance of the victims varied; some prisoners were from the surrounding villages, others had to be transferred from countries as far as France, Germany, Austria, Belgium, Czechoslovakia, USSR, Greece, Yugoslavia, and Macedonia. The assessed biological profile includes the ancestry component. The majority of the assessed ancestry was European after application of both free to access software (*Ancestrees* and *Cranid*). Four skulls were estimated as Northeast African by both computer programs. The programs used cannot pinpoint the assessed skulls to a specific country, where the persons ancestors lived, but provides the researcher with information on the broader geographic area. Here Northeast Africa refers to the MENA demographic region (Middle East and North Africa), which includes countries such as Israel [153]. From historical sources, we know that many Jews died in Treblinka, and the Jewish ghetto police badge from Falenica found among the artefacts supports the claim that Jewish people were present amongst the victims. Three skulls were assessed unequivocally South Asian. Again, it is a quite broad geographic region which encompasses demographic regions of countries such as India, Pakistan, Afghanistan, Nepal, Sri Lanka and others. From various interdisciplinary research [154]–[157] we know, that the origin of Romani populations was from India. And the historical sources demonstrate that Romanis also died in Treblinka. Moreover, when we compare anthropological results with genetics results we notice, that for the skulls assessed anthropologically as NE African, haplogroups are N1b1b and the subclades of R0, those are frequently present in populations of North-East Africa and Ashkenazi Jews [158]–[161]. And a skull assessed as S Asian is of haplogroup K, which can be prevalent in Polish Roma people [162].

Then the ancestry of a person isn't always correlated with the person's geographical origin [3]. For future research we recommend stable isotope analysis, which could help in narrowing down the geographical provenance of the victims, which in turn could possibly help in personal identification. The forensic isotope analysis has proven to be very useful in reconstructing a person's geographic life history and dietary habits in many cases of humanitarian crisis [163], such as identification of dead migrant remains on the USA/Mexico border [164] or identification of migrants from Syria in Italy and Greece [165]. Despite the commingling of the skeletons, the overall preservation state of the skulls was rather good, so it is possible to make facial approximations of many of the recovered victims. Even though facial approximation is not considered a primary method of identification [166], it could benefit the personal identification process in this case, and it should be one of the next steps of the research on the skeletal material, on the land of former KL Treblinka I, recovered from the clandestine burial pit. One of the primary methods of personal identification recommended by Interpol for a mass event [41] is genetic analysis. The genetic kinship analysis performed did not show any relatedness between the victims of Treblinka I penal labor camp. Further studies are being conducted to obtain higher quality DNA extracts, and so - better DNA profiles. However, even after full profiles are obtained, the identification cannot be possible without the reference material. Thus far, no positive identification of the studied victims has been obtained. An ongoing search for the families of Treblinka I victims is being conducted.

5.7. Conclusions.

The studied skeletal material represents the hard evidence of atrocities committed by Treblinka camp guards on their prisoners. This is the first time since the first half of the twentieth century when the victims' remains were physically examined. The non-invasive methods applied by scientists from 2007 contributed greatly to the knowledge of the spatial organization of the camp's structure, as well as the possible location of some of the mass graves, but they cannot fully replace the standard archaeological excavation. Thanks to the trauma analysis results, we may infer that the victims were brutally beaten around the time of death. Many of them fought back (as suggested by parry fractures and metacarpals' fractures) that can indicate they knew what was going to happen to them. Some of the victims were likely killed by forcibly having their heads placed on a wooden block or a stone and hitting them with possibly a mallet. Others were hit on the top of their heads with a bat or a plank or a similar object. Some were shot in the back of their head and others were cut through the brain stem or beheaded. Interestingly, all of the noticed perimortem trauma lesions were later verified by survivors' testimonies and were proven consistent.

The variety of the manners of death we observed can suggest that there were multiple assailants during the killing, and possibly the murders took place in various locations. The material that we examined was exhumed from only one of many clandestine mass burial pits on the Execution Site of Treblinka camp. The archaeological survey shows there are several more graves nearby our exhumed pit.

Our research shows that hard physical labor, poor sanitary conditions, overcrowding, poor nutrition rates and epidemics were not the only reasons for the early demise of hundreds of thousands of people imprisoned by the Nazis during the Second World War in KL Treblinka. Many of the captives were brutally murdered by their guards, and those crimes deserve to be prosecuted to bring justice to the victims and their families.

6. The Treblinka victims fought back. The analysis of the seven "Trawniki Men" buried in single graves in the former extermination and labor camp.

6.1. Abstract

The Treblinka extermination and forced labor camp were stationed by only a few SS soldiers and around a hundred watchmen who kept guard over thousands of prisoners. The watchmen, who were also called "Blacks", had a lower position in the Nazi hierarchy than SS soldiers, but they were, nevertheless, integral to the implementation of the "Operation Reinhard" plan. They were brutal, ruthless, and caused fear among the Nazi camps' prisoners.

"The Blacks" were intermediaries between the camp's inmates and the commanding crew, so in cases of a prisoners' riot, they were the first target. The historical records mention several incidents where the watchmen died at the hands of the captives. However, little is known how the dead bodies of the guards were treated nor what the funeral customs looked like in the camps.

In 2019, during the archaeological survey on the former Treblinka extermination and forced labor camp, a row of individual burials was detected and uncovered. Seven of those graves were explored to identify the people buried in such a place in such an unusual manner and to find out what had caused their death. A thorough multidisciplinary study, combining the disciplines of archaeology, anthropology, medicine and genetics provided the answer to our research question.

Based on archaeological artefacts we may infer that the graves belong to the Treblinka guards. The anthropological analysis shows that the biological profile is consistent with the antemortem data of the Treblinka watchmen. Additionally, the perimortem trauma study revealed that at least two out of the seven men who had been examined died a violent death. To narrow down the identification process, we created a facial approximation based on one of the preserved Wachman's skulls.

Our results contribute to worldwide knowledge of the funerary customs prevalent in the concentration camps. The Nazi camps' watchmen graves had never been analyzed nor published anywhere before. That makes our results unique on a global scale.

6.2. Introduction

From the summer of 1941 until the summer of 1944, Germans enslaved hundreds of thousands of people in a forced labor camp, Treblinka I [113]. The camp's conditions as well as the camp guards' brutality were so horrific that a plethora of the people did not survive the imprisonment [129]. The crew of the camp consisted of over a dozen SS-soldiers and around a hundred Watchmen keeping guard over several thousand prisoners [21]. The Watchmen (SS-Wachmannschaften) were mostly volunteers and recruits from prisoner-of-war camps, who were trained in a specially prepared facility in Trawniki near Lublin to become Nazi collaborators [25]. In contrast to the Treblinka camp victims, the names of the majority of guards were known [21], [22], so, in theory, they could have been prosecuted after the war for the crimes they had committed if they had been caught and arrested.

Naturally, the captives rebelled against the guards on multiple occasions [21]. One of the most famous documented revolts was the uprising in Treblinka on August the 2nd 1943, when the prisoners set the camp buildings on fire. During that riot, over 800 captives lost their lives and only 200 were able to escape [167]. Several guards also died on that day. The historical sources mention a number of situations where the camp guards fell as casualties. However, little is known about where the fallen guards' bodies were buried nor about the manner of their interment.

In November 2019, during an archaeological survey on the grounds of a former Treblinka I forced labor camp [116], [168], a row of seven individual graves was uncovered. The graves were distinct from the mass burial pit located only a couple dozen meters from the row [116], not only because they contained single bodies, but also for the artefacts interred with the bodies. We formed a hypothesis, that the graves could belong to the camp guards, who were lower in the camps' hierarchy than the SS-soldiers but were above the prisoners. That status permitted their bodies to be buried in the camp cemetery with honors.

The in-depth archaeological, anthropological, medical, and genetic study was performed with the ultimate goal of finding out who the people buried in such a special manner were and how they died. Using the results of anthropological and genetic study, we performed a 3D facial approximation of one of the victims to provide identification leads.

6.3. Material and methods.

6.3.1. Material.

The archaeological survey that was conducted in November 2019 included two sites (fig. 1). Site 1 covered the ground of the bus parking lot and contained a clandestine burial pit (see Drath et al., 2023). Site 2, located in the woods, contained an area of 1300 m^2 with rows of longitudinal depressions that could signify the location of burials. Those sinkholes formed a line along the east-west axis for about 20 meters. The cavities themselves were oriented south-north. The area of site 2 was densely wooded, therefore it was impossible to establish surveys of regular depth, width, and length. During the survey in places of marked sinkholes, under the layer of humus, dig outlines of potential burials were noticed (fig. 2). The outlines were fully exposed, cleaned and documented. In total, seven burials were uncovered. In two cases it was clear that the original burial outline was distorted. One was a probable robbery action, the other was a survey that had been carried out previously by dr Sturdy-Colls [169].

Figure 4. Localization of the site nr 1 (stanowisko nr 1) and nr 2 (stanowisko nr 2) with sector division.

Figure 5. The aerial shot of the single burials row in site 2.

6.3.2. Methods.

a. Archaeological methods.

Before the exploration began, the site area was penetrated with metal detectors. All the findings were inventoried on an ongoing basis, and their locations were measured within designated sectors.

The first stages of the excavation were conducted with the use of a digger with a slope bucket, which removed small layers of topsoil to the level of bedrock. The work of the digger was done under the constant supervision of archaeologists and anthropologists. The information board served as a fixed height point for the measurements, and it was 10 cm above the ground level. The outlines of burial pits were recorded at this level. The documentation included measurements, drawings, photographs and descriptions. Then further exploration of the graves began. The cross-section of the individual burials was not made, except for two situations where the disturbance in the grave's continuity was noticed. There the burial pits were cut in half, and one half of them was explored with shovels until the coffin lid was uncovered. The cross-sections of those graves have also been documented. The early stages of exploration in all burial pits were done with the use of machines, and later cleaned manually with plastic shovels and instruments with blunt edges. After the skeletons had been cleaned, the written graphic, photographic and descriptive documentation was prepared. All items found during the exhumation were inventoried and assigned to specific remains or layers in which they were found. The skeletons were packed in cardboard coffins and transported to Szczecin for anthropological, medical and genetic analysis.

Figure 6. The Mauser rifle case found in the soil of site 2.

b. Anthropological methods.

To evaluate the biological profiles, methods commonly used by forensic anthropologists were applied that are in accordance with Daubert standards [170]. Depending on the skeletons' preservation state, the biological age was estimated with the use of auricular surface morphology [48], pubic symphysis morphology [47], teeth eruption sequence [171], teeth crown abrasion [172], teeth root translucency [173] and the ossification state of long bones [46]. The biological sex was determined with the use of skeletal elements' morphological features, mainly coxal bone and skull [54], and by applying metric methods on coxal bone [51] and femoral or humeral head diameter [53]. The stature was calculated with the use of femoral length measurement and a regression formula based on assessed sex and ancestry [57]. The ancestry was estimated from the skull measurements with the application of two types of software, Ancestrees [55] and Cranid [119].

The skeletal trauma was described by providing information on the time of trauma occurrence, the location, the size of the lesion, the type of trauma, lesions margin structure and color [71], [79]. When referring to the time of trauma occurrence, the anthropological meaning of the term perimortem was used [58]. In cases of gunshot trauma, the diameters of entry and exit holes were measured and the bullet trajectory was predicted when possible. We used the endoscopic camera "WiFi Endoscope- HD 1200P" to look inside of the cranium and search for traumatic lesions. Every traumatic lesion was additionally photographed with a scale. Based on the noticed perimortem trauma lesion, the forensic pathologist was able to determine the health consequences for the victim and determine the cause of death.

The preservation state of the two skulls was acceptable for facial approximation. Those skulls were scanned using the Artec Spider 3D scanner and software Artec Studio 13. We created a facial approximation of the skull from the skeleton number 2. In the reconstruction process, the Manchester method guidelines were followed [174]. Moreover, we combined the anthropological and genetic results to infer the phenotypical features of the face. The soft tissue modelling was performed on ZBrush software. The soft tissue thickness pegs were constructed following the recommendation of De Greef [175] based on the assessed biological profile of the victim. The nose was shaped with a combination of Gerasimov [176] method, Wilkinson [177] and Rynn [178] guidance. The eyes were created following the methodology by Angel [179], Guyomarc'h [180] and Fedosyutkin-Nainys [181]. The mouth shape was modelled after Wilkinson [182] and Houlton [183]. The shape of the ear was reconstructed following Stephan and Devine [184] and Guyomarc'h [185] methods. The facial reconstruction was used to aid in the identification process and for the educational purposes.

c. *Genetic methods.*

Genetic research was carried out in stages and required the selection of specific procedures and methods. The aim of the first stage was to obtain the highest possible DNA template. Methods routinely used in the Department of Forensic Genetics were selected.

Only teeth taken from the jaw were selected for DNA isolation. The quality and quantity of the obtained extracts were measured by Real-Time PCR, using an amplification kit designed specifically for material with potentially low DNA template, which allows estimating the degree of DNA degradation and the presence of PCR inhibitors.

In order to assess the purity of the obtained extracts and determine the biological sex of the individuals, the samples were subjected to STR profiling using a highly sensitive amplification kit designed specifically for forensic genetics. All the above-described activities and analyzes were performed at the Department of Forensic Genetics of the Pomeranian Medical University in Szczecin.

STR markers were amplified using the GlobalFiler™ PCR Amplification Kit (Thermo Fisher Scientific) according to the manufacturer's protocols. Yfiler™ Plus PCR Amplification Kit (Applied Biosystems) was used to analyze Y-STR markers.

Mitochondrial DNA sequences have been determined for the HV1 and HV2 hypervariable regions. The amplification primer sequences were in accordance with the literature (180) for primer pairs: 15971 and 16410 for HVI and L15 and R429 for HVII. Mitochondrial DNA haplogroups were analyzed using two phylogenetic tools: EMPOP database (http://empop.online) [61] and HaploGrep (https://haplogrep.i-med.ac.at) [62].

IonTorrent technology was used to sequence the entire mitogenomes. The libraries were prepared using the Precision ID Library Kit and Precision ID mtDNA Whole Genome Panel.

Sequencing was performed on an HID Ion S5™ sequencer. Sequencing data was analyzed by Torrent Suite 5.10.2 and mtDNA sequences were compared to the Cambridge Revised Reference Sequence (rCRS) by Torrent Variant Caller software (all above: Thermo Fisher Scientific).

6.4. Results.

6.4.1. Archaeological results.

The orientation of the graves was in all cases north-south, with heads facing south. The depth of the burials ranged from 80 to 125 cm. Each body was buried in a separate wooden coffin. All the graves were more or less disturbed. In the cases of grave nr 1 and nr 2, the diggings that caused the grave destruction were visible in the plan: grave nr 1 was a robbery action, grave nr 2 was caused by a previous archaeological survey. In the other graves, no traces of such activity were registered in the plan. However, considering the fact that the skeletons were not in anatomical order, certain skeletal elements were disrupted. The anthropologist stated that the graves had been disturbed sometime after the burial. The intervention had to be made at a time when the grave was still clearly visible on the field, because it did not extend beyond the original burial pit, which would have left visible traces, as was in the cases of graves number 1 and 2. Only the remains that were laid in graves nr 1 and 2 were in anatomical order, and in the case of the skeleton from grave number 2, valuable grave goods were present (golden wedding ring). In two cases, funeral wreaths were found. The first, braided from wire with metal leaves, was found in a layer of topsoil and was originally placed on a grave mound (grave 1), the second, made of a wire hoop decorated with multicolored plastic flowers, was placed directly on the lid of the coffin (grave 4; fig. 4). Among the grave goods found within other skeletons, there were plastic combs, German uniform buttons, wedding rings on two skeletons (the other one was a metal ring on skeleton number 7), a guards whistle with the skeleton nr 2 (fig. 5), bullet cases (fig. 3), a pocket knife. Only with the skeleton number 6 no artefacts were found.

Figure 7. The grave number 4 with a funeral wreath.

Figure 8. The metal whistle found in grave number 2.

6.4.2. Anthropological results.

The preservation state in the majority of the skeletons was very poor. The skeleton number 1 was preserved quite well, with only a few bones missing from the feet and hands, patella and one cervical vertebrae. There was no texture damage on the bone periosteum, no signs of weathering. The structural damage was typical for coffin burials. On some skeletal parts (vertebra, rib ends), the dried entomofauna remained. The skeleton number 2 was also preserved well, with a few elements missing, mainly from feet and hands. However, here we observe massive signs of a weathering process; the majority of the periosteum is flaking and separated from the bone core. The skeletons numbered 3 to 7 are poorly preserved and in a fragmentary state, with many elements missing, and with very advanced taphonomic changes in the texture and structure of the bones.

The results of the assessed biological profile are presented in table 1. The skeletons were numbered with the same numbers as the graves. The biological age of four people (skeletons number 4 to 7) was below 25 at the time of death. The age-at-death of three people (skeletons number 1 to 3) was estimated to be over 30. It was possible to estimate the sex of six people, in case of the seventh person the sexual dimorphic traits were not preserved. Two of them were males, four were possible males. There was no female sex in the studied material. It was possible to assess the biogeographical origin in two cases, where there was no structural damage to the skull bones. In both cases, the result rendered the European ancestry. The stature was evaluated in six cases (except for skeleton number 7), and it was in the range of 157 to 176 cm for all six people.

Table 11. The results of anthropological analysis (GST- gunshot trauma; BFT- blunt force trauma).

The skeleton number	Age	Sex	Ancestry	Stature [cm]	Trauma
1	34-44	Male	European	165-173	No
2	34-49	Male	European	169-176	3x GST to the head
3	34-44	Male?	NA	157-165	No
4	18-25	Male?	NA	164-174	BFT to the head, GST on the patella
5	18-25	NA	NA	165-172	No
6	18-25	Male?	NA	167-174	No
7	18-30	Male?	NA	NA	No

The perimortem trauma was observed on two skeletons. On skeleton number 2 there was perimortem trauma on the skull (table 2).

Table 12. The traumatic lesions observed on skeleton nr 2.

Location	Trauma
Skull- occipital bone	1. An oval defect on the left side of the bone, near the lambdoid suture, of dimensions 14x9mm, on the bottom side of the defect there is a slight beveling. 2. A circular defect in the area of occipital protuberance, in the middle of the squama, approximately 9x11mm in size. On the left margin of the defect there is a slight crater-like collapse of the bone fragments. From the defect goes a line of incomplete fracture that reaches the skull base. 3. An incomplete fracture running from the foramen magnum at the back of the left articular surface towards the back of the skull for a length of about 22mm. 4. On the skull base, next to the spheno-occipital synchondrosis, there are raised, bulging bone structures with incomplete comminuted fractures and green bone staining.
Skull- left temporal bone	5. A funnel-shaped defect along the mastoid process, of a maximum width about 11mm. The defect runs slightly anteriorly inferior. On the anterior side there are perpendicular lines of incomplete fractures that extend from the fracture edges. 6. An incomplete fracture running parallel to the injury described above, running across both edges of the external auditory meatus. The fracture line runs up the bone for about 18mm.
Skull- left maxilla	7. An incomplete fracture running parallel to the zygomatic-maxillary suture from the lower edge of the orbit downwards and to the posterior side. There the fracture line changes into circular defect that exposes maxillary sinus. It is impossible to estimate the time of the defect formation.

The spotted gunshot injuries on the skull indicate at least three shots that were possibly inflicted by a weapon of the same caliber (fig. 5 and 6).

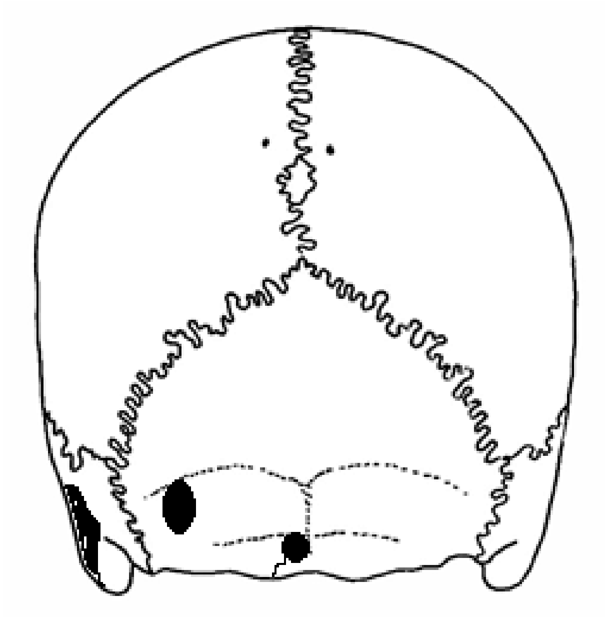

Figure 9. The posterior side of the skull from skeleton number 2 showing traumatic defects in black.

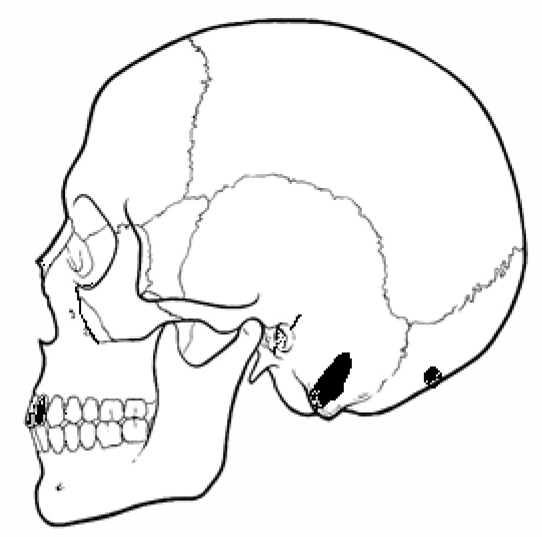

Figure 10. The left side of the skull from skeleton 2 showing traumatic defects in black.

It is not possible to determine the order in which the shots were fired as not all injuries resulted in additional fractures, therefore it is not possible to apply the Puppe's rule [186]. Nevertheless, it is possible to draw some conclusions about the possible bullet trajectory or the angle of bullet penetration on the skull. The injury number 2 has features of a bullet entry hole with a crater adjacent to the entry hole on the inner side of the bone and radiating incomplete fractures. There are no definite traces of the bullet's exit. It is possible that that the bullet ricocheted off the internal structure of the skull and exited through the foramen magnum, hitting the edge of it and causing fracture number 3. The oval shape of injury number 1 may indicate that the bullet penetrated the skull at an angle different than 90°. Based on the analysis of the bone beveling at the lower edge of the defect, it is assumed that the shot came from above. The bullet may have hit a part of the skull base, causing incomplete fractures and bending of the bone fragments from the inside outwards to the right of the skull base. The green staining can mean that the bullet did not exit the skull, but stuck in the bone and degraded due to erosion. The trajectory of the bullet of injury number 5 may be consistent with the shape of the defect. After using the probe to assess the bullet trajectory, on the underside of the injury, it can be assumed that the bullet hit the posterior wall of the maxillary sinus, causing a defect on the posterior side and an incomplete fracture on the anterior side, described as injury number 7. Based on the pathology report, the described gunshot injuries, especially those of number 1 and 2, penetrated into the cranial cavity and caused extensive damage to the central nervous system, resulting in the death of the victim.

On skeleton number 4, perimortem lesions were observed on skull bones and right patella (table 3).

Table 13. The traumatic lesions observed on skeleton number 4.

Location	Trauma
Right patella	Imbedded bullet tor shrapnel fragment on the anterior side of the patella. No additional fractures were detected.
Skull	1. Right parietal bone- a possible depression fracture in the middle of the bone. 2. Left parietal bone- an incomplete fracture extending from the center of the bone to the left to the edge of the bone. Part of the bone, behind the fracture line is concaved, possibly due to taphonomic process. 3. In the posterior part of the left parietal bone there are fragments from the comminuted fracture, possibly the remains from the radiating fracture type. Fractures caused separation of two fragments near the lambdoid suture measuring approximately 34x41mm and 33x37mm. 4. Irregular injuries of unknown etiology are visible in the area of *glabella*. To the right from the point *Glabella* there is a semicircular lesion of diameter around 7mm. Another semicircular injury is on the left from the *Glabella*. From the injury goes a crack up the bone for a length of 4mm. 5. Right maxilla- perimortem fracture near the first molar.

The embedded shrapnel or a bullet in the right patella caused no additional injuries nor fractures to the patella, nor to the skeletal elements forming the knee. There is no definite gunshot trauma to the skull detected. Injuries numbered 1 to 3 have features typical of a blunt force trauma, but it is not possible to match a specific type of tool that caused specific damage nor to infer the order of the blows. The state of preservation did not permit a more thorough analysis of the traumatic lesions. The possible cause of death were the injuries to the central nervous system.

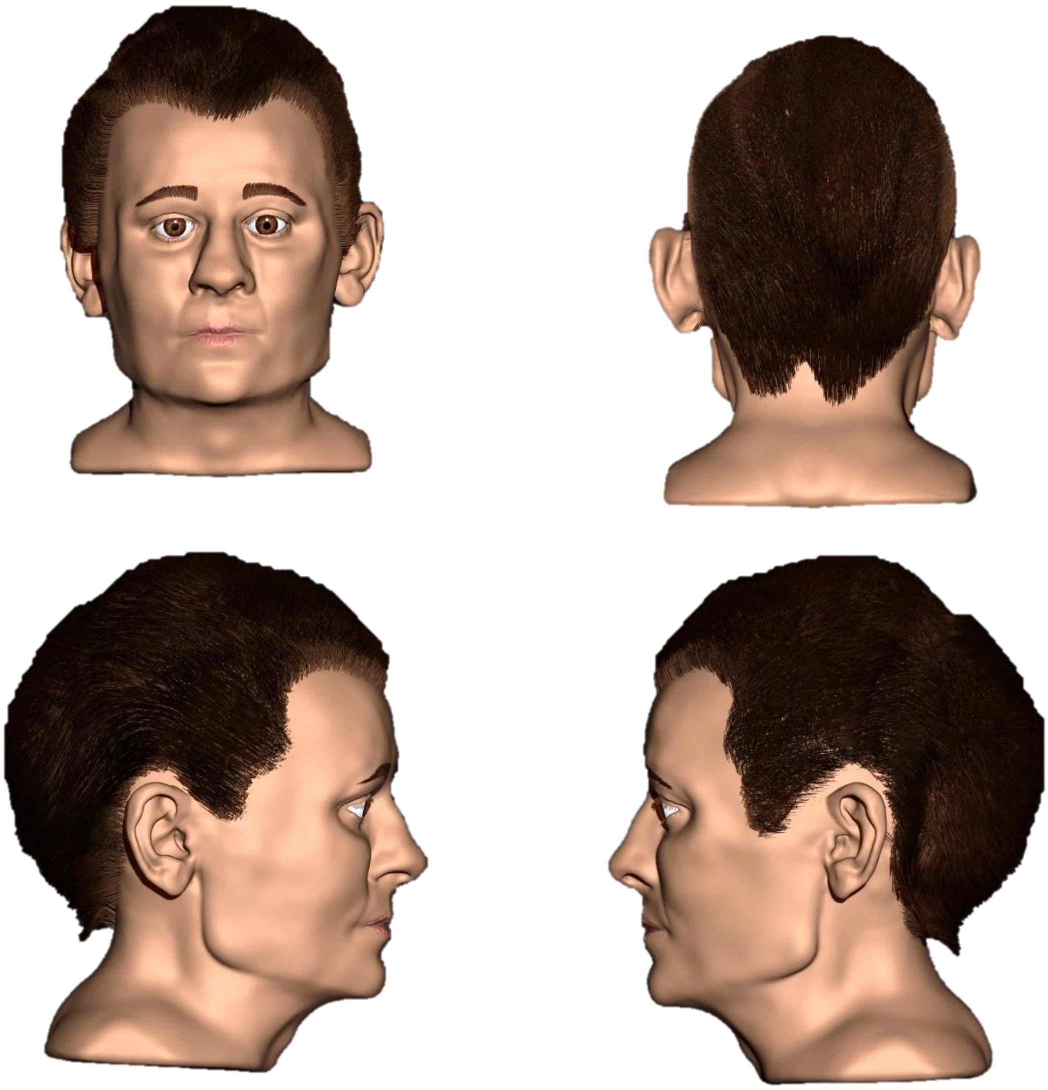

Figure 7-10. The facial approximation of the person buried in grave number 2 (from the top left: front, back, left, right).

Figures number 7 to 10 show the result of a complete facial approximation, which revealed the face of an adult male. His nose is long and narrow, slightly bigger on the right side of the face, prominent, high-bridged and of an aquiline shape with a blunt tip facing downwards. The ears have detached earlobes, but possibly were not protruding. The lips were of medium width, with a well-defined "cupid bow", slightly asymmetrical in the lower lip. Face slightly narrowing towards the chin. The forehead shape is straight.

6.4.3. Genetic results.

The genetic results of sex estimation and mitochondrial haplogroup type shows table 4.

Table 14. The results of DNA profiling within Global Filer and Y Filer Plus human identification systems (TFS), mtDNA HV1 and HV2 region sequencing and whole mitogenome sequencing of remains from individual burial pits (ISFG Washington 2022).

Skeleton number	Global Filer™	YFiler Plus™	Genetic sex	mtDNA haplotype	mtDNA haplogroup
1	Full profile obtained	Full profile obtained	Male	HVR1, HVR2 and WG obtained	H
2	Full profile obtained	Full profile obtained	Male	HVR1 and HVR2 obtained	R0
3	Profile not obtained	Profile not obtained	Male	Not obtained	Undefined
4	Full profile obtained	Full profile obtained	Male	HVR1 (16024-16350), HVR2 and WG obtained	U5a1a1h
5	Partial profile showing signs of degradation	Partial profile showing signs of degradation	Male	WG obtained	J1c1b1a1
6	Partial profile showing signs of degradation	Full profile obtained	Male	HVR1 and HVR2 obtained	U5a2a
7	Partial profile showing signs of degradation	Partial profile showing signs of degradation	Male	WG obtained	H28a

As a result of genetic analysis, the biological sex of all the studied individuals was found to be male. Out of seven studied samples, for six people it was possible to obtain a genetic profile and estimate mitochondrial haplogroup. The results are in line with anthropological analysis on ancestry estimation.

6.5. Discussion

The single burials that were uncovered during the archaeological survey in 2019 on the land of the former Treblinka extermination and forced labor camp contained individual skeletons from bodies that were buried in separate coffins. At the time of the discovery, it was unknown who the people buried in such a distinct manner were. A team of experts from various scientific disciplines was appointed to identify those deceased and, when possible, to determine the cause of their death.

The preservation state described by an anthropologist was correlated with the genetic analysis' success. Those skeletons that were very well preserved contained a high enough amount of DNA for deeper genetic study. The relation between the bone structural preservation state and the possibility of full DNA profile acquirement was studied and confirmed many times by various researchers [187]–[189].

Knowing that the deceased were buried in individual graves, that they were interred in coffins with honors, which is proved by funeral wreaths found on top of two coffins, it may be inferred that those people played an important role in the Treblinka camp settings. The evidence in the form of artefacts recovered from the coffins, such as a metal whistle, bullet cases and buttons from a German uniform, point to the possibility that the people buried in the studied graves belonged to the camp's guarding crew.

The sentry formation units from Trawniki were created between August and September 1941 [25]. The unit had two official names: from fall 1941 to March 1942 it was known under the name Wachmannschaften des Beauftragten des Reichsführers SS Und Chefs der Deutschen Polizei für die Einrichtung der SS Und Polizeistutzpunkte in neuen Ostraum, and from April 1942 to summer 1944 it changed its name to Wachmannschaften des SS und Polizeiführers im Distrikt Lublin [190]. The formation consisted of indigenous collaborators, who were cold-blooded killers bound neither to territory nor nation but to leaders and quests [26]. They underwent training in Trawniki, near Lublin, where in September 1941, the SS set up a training facility near the already existing forced labor camp for Jews. The "Trawniki-men" known also under the name "Blacks" or "Wachman" played an essential role in the Operation Reinhard, without them Nazis couldn't implement their "Final Solution of the Jewish Question" [21], [26].

In Treblinka they were mostly Ukrainians, Lithuanians and Latvians and they were responsible for keeping the guard over the prisoners [113]. They were all males, mostly young, aged under 30. But there were also much older people, even over 40 years-old. They were equipped with Mauser vz. rifles and bayonets [21]. Although they played an important role in the camp, they were not equal in hierarchy to German SS-soldiers [191]. They had to follow the orders given by the Germans. They were not permitted to beat prisoners, but there were a few exceptions. From the written survivors' testimonies we know that Franz Swidersky was allowed to perform executions on captives. The watchman Braun, who was a Russian volksdeutsch, was allowed to beat prisoners [21], [22], [113].

It is unknown how many times or how often the prisoners of Treblinka camps resisted the oppressors. The biggest revolt that was documented was on August the 2nd 1943 [192]. The prisoners from both camps (extermination and labor camp) united. They duplicated the key to the guardhouse and stole weapons, ammunition and grenades. They started shooting at the guards, and set several buildings on fire. They rushed to the main gate, which they managed to force open. However, they couldn't damage the gas chambers nor did they break the telephone line, so soon enough the backup from the nearby stations came to hunt and capture the fleeing prisoners. In total, the uprising lasted no more than half an hour. It is estimated that only around 200 prisoners managed to escape, the majority of those who participated in the revolt died in action. The exact number of casualties from the Treblinka staff is unknown [21], [113], [167], [192], [193].

The assessed biological profile is consistent with the historical records describing the Treblinka watchmen [194], [195]. The biological sex was confirmed using anthropological and genetic methods. The age-at-death, estimated by the anthropologist, shows that over half of the studied men were under 30. The biogeographic origin evaluated by the anthropologist and geneticist point to European origin. The traumatic lesions noticed on two people could not be self-inflicted. The multiple gunshot wounds on the skull of skeleton number 2, of which two were in the back of the head, exclude any possibility of suicide [79]. One of the entry wounds on the occipital bone has morphological characteristics typical for a contact shot [196], meaning that the perpetrator put the gun against the victim’s head. A similar manner of death has been confirmed with blunt force trauma and gunshot trauma on skeleton number 4. The blunt force trauma injuries are situated above the so-called Hat Brim Line [72], which is commonly linked to interpersonal violence. The fact that the bullet stuck in the kneecap and did not produce any further fracture around the impact area, can indicate that the energy of the impact was very low [197]. This could have been caused by either the ricochet of the bullet from some other distant object, or the malfunction of the firing weapon. It cannot be excluded that the weapon was self-made.

The uprising of the German camp prisoners happened in many other camps as well. Very well documented was the uprising in the Sobibór extermination camp on October 14th 1943 [198]. Sobibór was one of three main extermination camps set up by Nazi Germans. The other two were Bełżec and Treblinka [194]. After the Bełżec was liquidated, the prisoners in Sobibór knew that it was their last chance to riot. It is estimated that 275 people escaped from the camp, 40 prisoners died in action and 12 Germans were killed by the combatants [199]. After the revolt was contained, the bodies of the fallen Germans were lavishly buried with funeral wreaths on their coffins [200]. This example shows the way how Germans treated their fallen colleagues’ bodies, the funeral rites in the extermination camps. That can explain why on two coffins from Treblinka we found the pieces of funeral wreaths.

The absence of funeral wreaths on other coffins, as well as the absence of other significant grave goods doesn't mean that the other five people were buried in a different manner. It has been documented in many historical sources that after the Treblinka camp was shut down, many graves were robbed by local treasure hunters [130], [201]. From archaeological analysis, we know that almost all of the seven studied graves have traces of postmortem interference. Because the robbing ditches did not interrupt the continuity of the grave's outline, they had to be made at a time when the graves were clearly visible in the field and the person who made it knew where to dig in order to reveal the fragment of interest. Traces of damage or tampering were especially visible in the torso and head areas, which is where the personal items might be expected to be found. In grave number 3 there was no disruption in the roof layer, but the skeletal remains were completely disturbed, not only in the trunk and head areas. Probably the only undisrupted grave was number 2, as evidenced by the intact arrangement of the remains and the fact that they were not deprived of a gold ring. The destruction and displacement of the skulls accompanying robbery digs in graves number 5, 6 and 7 could be done deliberately.

Because of the postmortem damage of the skeletons that was done either by the robbers or the environmental erosion, our study faced limitations regarding the process of the components biological profile assessment and perimortem trauma analysis. We cannot know if all the people buried in site 2 died a violent death, possibly during the uprising or some other incident, or maybe they died because of some disease that was circulating in the camp at those times. We know from the historical records, that in Treblinka there were several cases of typhoid fever outbreaks, resulting in many deaths [21], [22], [113], [129].

Another consequence of skeletons' incompleteness is the difficulty with personal identification of the deceased. The names of almost all the Treblinka staff are publicly known [129], [194], but it will be impossible to identify them with a use of DNA or odontology without any reference samples. One of the possible methods of identification in such cases, is through facial approximation [166]. The most famous example of personal identification from a photographic picture was the case of John (Ivan) Demjanjuk, a Nazi concentration camp guard. A retired man from Cleveland, Ohio, was accused of being a watchman called "Ivan the Terrible" stationed in Treblinka camp during the war [58], [145]. That case showed the need for rigorous scientific standards in personal identification from photographs. Although the method is far from perfect, there are many reports of forensic facial approximations using that produced successful identification [202], [203]. In our study we were able to compose a face of the person buried in grave number 2, the person who probably died due to a gunshot wound to the head. We hope that the face we present here will serve in the personal identification process when comparing the facial features with the watchmen's ID book photographs.

More details on the genetic analysis and facial approximation process done on the "Wachman" skeletons will be provided in forthcoming publications. For future studies we recommend exploring further the individual graves that extend along the studied row on the site 2 of Treblinka camp.

6.6. Conclusion

The combined results of archaeological, anthropological, medico-legal and genetic analysis allow us to conclude that the individual graves situated on the former Treblinka extermination and penal labor camp belong to the camp's guards. The trauma analysis results allow us to deduce, that some of the deceased died during the famous Treblinka uprising in August 1943, or some other riot created by the Treblinka captives.

The analysis of the World War II camp guards' graves was never published in any peer-reviewed literature, which makes our study unique. With the advancement of new personal identification methods, we can gain more information on who the guards in Nazi concentration camps were. Moreover, we contribute to the knowledge of funeral rites prevalent in those camps, which like many other aspects of the concentration camp's culture, remains obscured.

7. Conclusions.

Based on the research results the conclusions can be drawn:

1. In the both studied samples, the cranial perimortem trauma was prevalent. In Stutthof sample it was observed on 53% and in Treblinka on 70% of the preserved skulls.
2. In Stutthof material only three postcranial bones showed perimortem fractures, and majority of impact points were located above the Hat Brim Line or on the occipital bone. That could be interpreted as execution from behind, or a surprised attack.
3. In Treblinka material the perimortem fractures are visible also on postcranial bones, like ulna, scapula, clavicles, metacarpals. Moreover, there are many cases of traumatic lesions on facial bones, maxilla and mandible. That can mean that the victims were harshly beaten around the time of death.
4. In both samples the variety of trauma patterns suggests multiple aggressors involved in the killing process and no state-regulated execution process.
5. Trauma pattern analysis proved to be critical in the cause and manner of death inference from skeletal material. It is advised to expand the study of perimortem trauma pattern with bone fractography research and implementation of bone radiology results in the analysis process.

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I was responsible for conceptualization, methodology, formal analysis, investigation, writing original draft, writing review and editing and visualization. My role in the article creation estimates around 55%.

Slaughtered like animals. Revealing the atrocities committed by the Nazis on captives at KL Treblinka I by skeletal trauma analysis. Humanities & Social Sciences Communications.

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DECLARATION

I hereby declare my contribution in the submitted articles' creation:

Skeletal evidence of the ethnic cleansing actions in the Free City of Danzig (1939-1942) based on the KL Stutthof victims analysis. Science and Justice, DOI: https://doi.org/10.1016/j.scijus.2023.02.003.

I was responsible for conceptualization, methodology, resources and supervision. My role in the article creation estimates around 5%.

Slaughtered like animals. Revealing the atrocities committed by the Nazis on captives at KL Treblinka I by skeletal trauma analysis. Humanities & Social Sciences Communications.

I was responsible for conceptualization, methodology, resources and supervision. My role in the article creation estimates around 5%.

The Treblinka victims fought back. The analysis of the seven "Trawniki Men" buried in single graves in the former extermination and labor camp. Journal of Archaeological Science: Reports.

I was responsible for conceptualization, methodology, resources and supervision. My role in the article creation estimates around 5%.

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Andrzej Ossowski