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„Few and well-healed? Injuries of the long bones of Avar period skeletons from the cemetery of Mödling - An der Goldenen Stiege"

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2 Abstract

The study of trauma can provide insight into the life and death of an individual and a community. In this thesis, the long bones (clavicle, humerus, radius, ulna, femur, tibia, fibula) of adult individuals (> 17 years old) buried in the Mödling - An der Goldenen Stiege cemetery in Eastern Austria, dating to the Avar period of the 7th-8th centuries, were examined for fractures and traumas. A total of 18 of 265 individuals (6.8%) exhibited antemortem fractures and traumas, resulting in 30 injury cases distributed over 2992 long bones (1%). Males were significantly more likely to be injured than females: 14 injured males versus 4 injured females. Although males also had more multiple injuries (7 males out of 8 individuals with multiple injuries), no significant difference was observed. Older individuals had significantly more injuries, with middle adults (35-50 years) exhibiting the highest frequency of injury. Contrary to the expectation that the upper extremity (clavicle, humerus, radius, ulna) would be more affected by injuries, the opposite was confirmed: the lower extremity (femur, tibia, fibula) had significantly more injuries (20 out of 30 injuries). The fibula alone accounted for ten of the 30 injuries and had an unusually high frequency of injury. The results obtained are consistent with other trauma studies on the Early Middle Ages, with many cemeteries associated with the Avars showing a surprisingly low frequency of injury, caused mainly by accidents and occupational hazards in agriculture and animal husbandry. The well-healed injuries to the long bones indicate the treatment and care given to people who were at least temporarily unable to contribute to their community. Although the last phases of the Avar period seemed to be characterised by more uncertainty and change, the population of Mödling remained a peaceful community that cared for its injured.

Contents

3 Introduction

The study of bioarchaeology makes it possible to reconstruct and interpret the lives and deaths of past people through their human remains (Larsen, 2015). The skeletal remains of an individual can reveal what has manifested itself through their life in the physical form, i.e., the bones, because of the links between an inherited genome and environmental factors (Lovell and Grauer, 2018). Careful examination of the bones can reveal sex and age at death as well as diseases or injuries that may have affected an individual during their lifetime or ended their life (White et al., 2012). What is left on the bones are changes in response to mechanical forces, including activities and stresses (Lovell and Grauer, 2018). Trauma, i.e., any bodily injury (according to Roberts, 2000), including fractures or soft-tissue injuries, can provide information on whether an injury is due to an interpersonal conflict or caused by an accident (Larsen, 2015).

In this thesis, the long bones of the Early Medieval cemetery of Mödling - An der Goldenen Stiege are examined for injuries, their immediate cause and implications for the life of the individual concerned, and also in the community context of the Avars.

3.1 Background information - Who were the Avars?

The Avar period is named after the Avars who supposedly came to Europe from the steppes of Eurasia in the 6th century. They were first mentioned in Byzantine sources dating back to the middle of the 5th century. The Avars established their presence in the Carpathian Basin from 558 AD to 796 AD and ruled much of Central and Eastern Europe from their power base located half way down the Danube (Pohl, 2018; Daim, 1984; Daim, 2003). Discussions about who exactly they were and where precisely they came from remain until today. Their empire, ruled by the Avar Khaganate, dominated Eastern Central Europe until the Franks defeated them around 800 AD. Their movement began in the 550s caused by numerous factors, possibly including the rise of the first Turkic Khaganate based in present-day Mongolia (Gnecchi-Ruscone et al., 2022; Bede, 2012). According to the present knowledge, the Avar Khaganate existed from the end of the 6th century A.D. until the beginning of the 9th century. It covered the Carpathian Basin, which refers to in today's terms: parts of present-day Hungary, Eastern parts of Austria, Serbia, Czech Republic, Croatia, Romania, and Slovakia (Herold, 2011; Bühler and Kirchengast, 2022a; Daim, 1984). The people of the Avars established a multiethnic empire in Eastern Europe with a mixed ethnic background with East Asian and Northeast Asian ancestry and were closely related to both ancient and modern Inner Asian peoples (Rubini and Zaio, 2011; Neparáczki et al., 2019 Maróti et al., 2022). Recently, genetic similarities were found in particular with an individual part of the Rouran period and with ancient individuals part of the Xiongnu from the East Asian steppe (Gnecchi-Ruscone et al., 2022). The Avar elites arrived in the Carpathian Basin as part of groups and intermarried for generations (Csáky et al., 2020). This seems to point to the direct migration of the Avars from the Inner Asia region and their Rourani origin (Kubarev, 2021).

In the absence of historical records of their own, the reconstruction of the history of the Avars comes from external sources from contacts with neighbouring countries (Pohl, 2018; Szenthe, 2019). In its flourishing period, the Avar Khaganate put the Byzantium and Franks on the defensive, while maintaining contact with distant peoples, such as the Turks of Central Asia. The Avars also had a decisive influence in restraining the Slavic expansion. The Avar military campaigns were capable of spreading death and destruction as a highly specialised war machine across the Byzantine Empire (Pohl, 2018). Despite many conflicts, the Byzantine Empire had a great influence on the people of the Avars, including their material culture (Daim, 1984). In historical sources, the Avars are described as warriors who mastered archery as well as other fighting techniques with weapons and the horse as a means of mobility, which led to military successes, especially after their arrival in Europe (Bühler and Kirchengast, 2022b; Bühler and Kirchengast, 2022a). These beliefs are complemented by the archaeological record, especially in the Early Avar cemeteries, where mainly men's graves were equipped with weapons, such as composite-bows together with arrows, sabers, belt-sets, jewellery, and sometimes horses in harness (Daim, 1984; Bede, 2012; Bühler and Kirchengast, 2022b). On the basis of grave goods, a relative and absolute chronology of the Avar period in Eastern and Central Europe has been established. Grave goods gave insight into social status, gender roles as well as mobility patterns (Daim, 1987; Bühler and Kirchengast, 2022b). However, the attribution of group membership, social status, or identity through grave goods and burial customs remains problematic. The grave and burial itself portray how the remaining wanted the deceased to be represented and may offer them the opportunity to reaffirm their ascribed status (Bühler, 2020). Consequently, the burial goods may not necessarily represent the deceased features. The Avars seem to have adopted the customary burial forms in their surroundings soon after they came to power, and the burial of the body in a stretched supine position with costume and various grave goods, weapons and food and drink remained obligatory until the end of the Avar empire (Daim, 1984).

The groups migrating from the steppe settled in the Great Plain and Transylvania, and in Transdanubia and in areas previously belonging to the Lombards. The various peoples inhabiting the area had some influence, as indicated by the row cemeteries, but cultural heterogeneity remained until the late 7th century, probably due to continuous new migrations of Eastern European groups as well as internal migrations (Szenthe, 2019). The Avars gathered in what is now the Carpathian Basin and it seems that they had a very hierarchical and complex social structure (Daim, 1984). The emergence of larger new cemeteries together with more material remains seem to point towards an increasing population with a sedentary lifestyle during the Middle Avar period (Pohl, 2018). According to the archaeological record, the influence of the Eastern steppe seemed to wane in the 7th century with less privileged warrior elites, while agriculture and animal husbandry were more suitable for the European area than in the steppe. After some adjustment, the Late Avar period became more homogeneous with similar archaeological records stretching over the whole Carpathian Basin (Daim, 1984; Pohl, 2018). However, it is unclear to what extent the original lifestyle and economic models were maintained in specific ecological niches or whether local variants were developed that passed on economic and cultural elements of the original nomadic lifestyle (Szenthe, 2019). One part of the nomadic heritage, which diminished after the settlement in the Carpathian Basin, was the significance of the horses and their burials (Bede, 2012). Starting in the 8th century, political relations became less stable and campaigns against the Avar empire were plotted. After possibly being unable to defend themselves anymore, the Avars disappeared from the archaeological and historical records (Daim, 1984). Avars provided themselves with what they needed on a daily basis, including food, textiles, and pottery, sometimes by subjugated groups. However, through foreign objects it has been made clear that they also accumulated wealth through raids and tribute payments. In the course of military campaigns they obtained not only necessary raw materials but also prestige goods (Pohl, 2018). In addition to political factors, the disappearance of the Avar empire was most likely influenced by environmental factors as well. An analysis of historical and palaeoenvironmental sources leads to the interpretation of a decentralisation of power and differentiation with greater autonomy. This meant settlement growth in more stable climatic conditions before the Carolingian power attacked (Preiser-Kapeller, 2018).

3.1.1 Regional distribution of the Avars in the Carpathian Basin

The settlement of the Avar people in the Carpathian Basin offers a vast amount of information, with more than 100,000 Avar graves studied until now. The Carpathian Basin covers a wide area, with Eastern Austria being the Western border (Daim, 1984).

In the Eastern parts of Austria, excavations provided insight into the Avar period in terms of chronology and burial customs, with sites such as Vösendorf, Bruckneudorf, Leobersdorf, Zwölfaxing, Zillingtal, Wien Csokorgasse 11, Sommerein, and Mödling. Most of these sites were exclusively cemeteries, to which no settlement has been found to date, with the exception of Zillingtal. Hence, little knowledge has been gained about the daily life during the Avar period and the associated settlements in the case of the cemetery of Mödling (Daim, 1984).

The cemetery of Mödling - An der Goldenen Stiege is one of the largest cemeteries in Eastern Austria with over 500 burials made up of all age groups of both biological sexes. The archaeological findings have been published in different publications (Daim, 1976; Distelberger, 1999; Matzner and Mödling, 1977; Schwammenhöfer, 1976; Eibner and Matzner, 1966; Matzner and Schwammenhöfer, 1973; Schwammenhöfer and Schwammenhöfer, 1971; Schwammenhöfer and Schwammenhöfer, 1972; Stadler, 2010). The anthropological analyses were conducted by Karin Wiltschke-Schrotta (Wiltschke-Schrotta, n.d.). New findings, reassessments, and new analyses within the ERC-funded HistoGenes project will be published in the coming years (online source: https://www.histogenes.org/). Falko Daim and Peter Stadler are planning a monography about the cemetery of Mödling - An der Goldenen Stiege with new data on the archaeological dating of the cemetery.

3.2 Trauma

The term trauma can be defined in a variety of ways but generally refers to "any bodily injury or wound involving either bone, soft-tissue, or both" (Roberts, 2000; p. 377). An alternative definition of trauma would be damage to living soft-tissue by external forces or mechanisms, both accidental and intentional (Adams and Hamblen, 1991; Lovell, 1997). Traumatic lesions and their development shed light on the life of an organism, including humans, and how they interact with their physical and sociocultural environment. The aim of trauma analysis in paleopathology, therefore, is to describe in detail a traumatic lesion in skeletal material with associated data on various past behavioural influences (Lovell and Grauer, 2018; Roberts, 2000). Studying injury morbidity and mortality may help assess the cultural, social, and environmental aspects of behaviour (Larsen, 2015).

As the definition of trauma may differ depending on the field of study, there are different forms how trauma can influence the anatomy of the body. In this thesis, only skeletal remains from archaeological material will be discussed. According to Bennike (2008), trauma can be grouped into fractures, sharp force injuries, crushing injuries, dislocations, and deformations. Furthermore, skeletal trauma may include trephination, scalping, mutilation, be of consequence of soft-tissue trauma, osteochondritis dissecans, spondylolysis, intentional or accidental tooth loss, and traumatic problems arising from pregnancy on the symphysis pubica (Bennike, 2008). In contrast to the comprehensive grouping of traumatic events, others have created four groups with ossification of soft-tissues, dislocation, extrinsically induced abnormal shape or contour, and fractures (Lovell and Grauer, 2018). However, of interest in this thesis are mainly fractures and soft-tissue trauma of the long bones.

When assessing traumatic lesions in skeletal remains, distinctions between antemortem, perimortem, and postmortem timing of the injury need to be made. A traumatic lesion that occurred antemortem refers to an injury before a persons death and shows signs of healing of the injured area. Perimortem injuries may have occurred around the time of death, indicating that the event was responsible for the death or occurred around that event. It is important to state here that causes of death can be very rarely established in skeletal remains; that is the reason for the term perimortal. Postmortem incidents, however, refer to fractures that occurred after the person's death and are usually changes caused by taphonomic processes, such as erosion, surface pressure, or water (Wieberg and Wescott, 2008). Figure 1 illustrates the steps to take while assessing trauma on skeletal remains and how to distinguish between ante/peri/postmortem injuries.

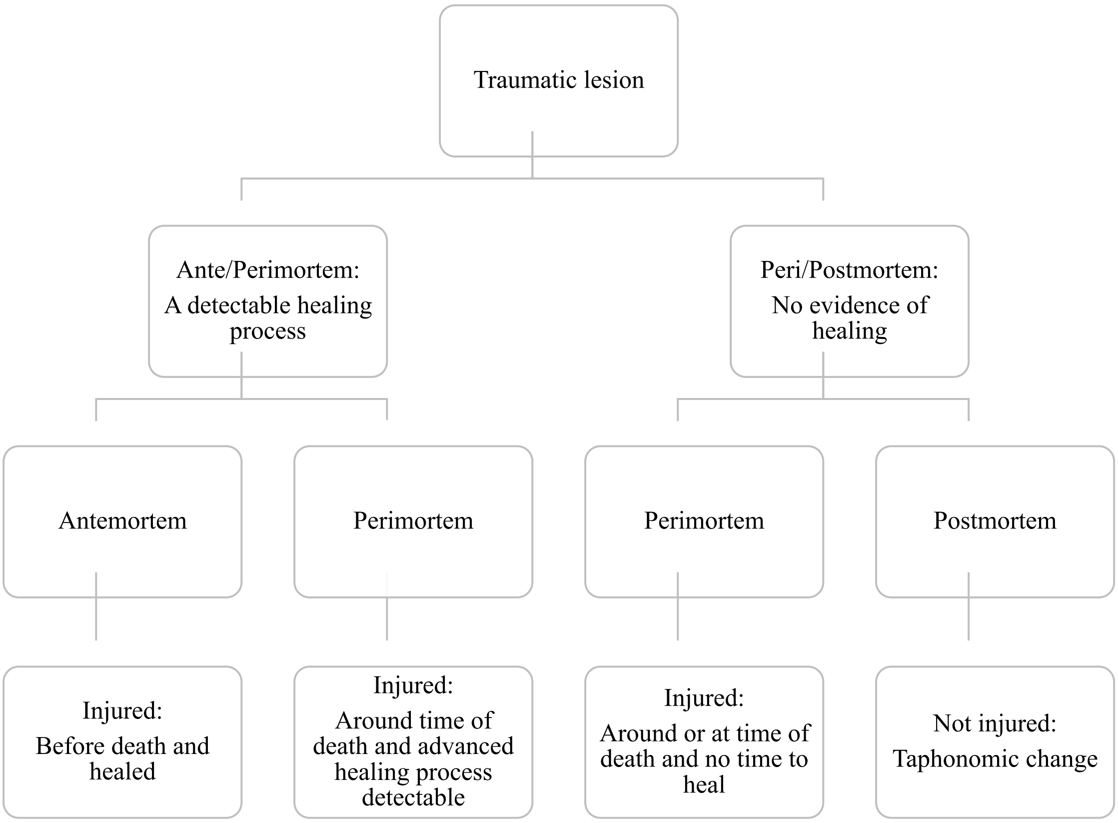

Figure 1: Steps to distinguish ante/peri/postmortem injuries (adapted from Walker, 2001, p. 577)

Whether a fracture can be identified as perimortem or postmortem depends mainly on the characteristics of the bone. This is related to the distinction between "fresh" bone, which retains moisture and breaks differently compared to "dry" bone. However, the moisture in the bone can remain some time after death, which makes distinctions between perimortem and postmortem fractures problematic. Other fracture characteristics used for the distinction between perimortem and postmortem fractures include colour variation on the bone surface and the cortical bone (internal and external), with homogeneous colour indicating perimortem fractures. Fracture morphology refers to the angle and outline of the fracture differing between "fresh" and "dry" bone. Fresh bone breaks with irregular edges and surfaces, whereas dry bone breaks parallel, diagonal, or perpendicular with several small fragments and surface cracking. However, all the mentioned criteria can vary with different circumstances (Wieberg and Wescott, 2008; Moraitis et al., 2008).

3.2.1 Trauma and its mechanisms

A fracture may be defined as either "an incomplete or complete break in the continuity of a bone" (Lovell and Grauer, 2018, p. 339). One could also say, a fracture is a "discontinuity of, or a crack in, skeletal tissue, with or without injury to overlying tissue" (Bennike, 2008; p. 310). Many different characteristics differentiating types of fractures are defined. First, different mechanisms are responsible for a fracture, with direct trauma breaking the bone at the point of impact and indirect trauma breaking the bone at another place than the point of impact (Figures 2 and 3). Fractures can either involve the joint as intra-articular fractures, or they can be extra-articular and do not involve a joint. They may be open, meaning that the injury is exposed through the broken skin and the bone may be visible (Lovell and Grauer, 2018). The different types of fractures and their injury mechanisms are summarised in Table 1.

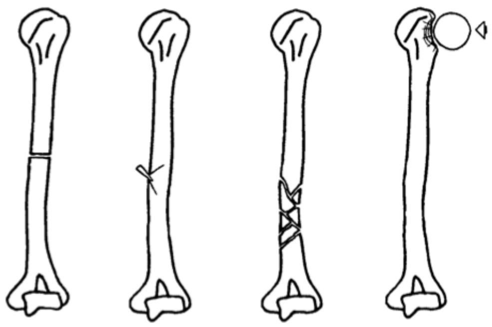

Figure 2: Fractures caused by direct trauma. The drawings show from left to right: transverse, penetrating, comminuted and crush (Lovell, 1997, p. 142)

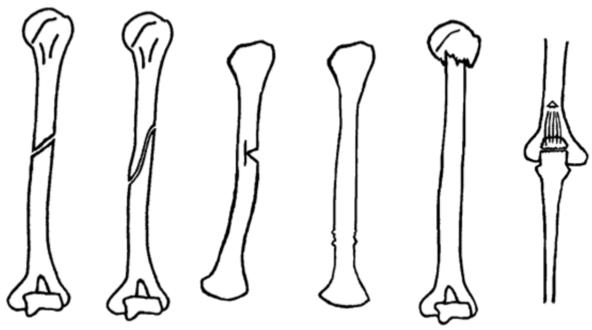

Figure 3: Fractures caused by indirect trauma. The drawings show from left to right: oblique, spiral, greenstick due to angular force, greenstick due to compression, impaction, and avulsion (Lovell, 1997, p. 143)

Table 1: Types of fractures and their mechanism of injury (modified from Lovell and Grauer, 2018, adapted from Lovell, 1997; Galloway et al., 2014)

Type of fracture	Mechanism
Indirect trauma	**break at other place than point of impact**
Crush - Depression	Crushing on one side of the bone
Crush - Compression	Crushing on both sides of the bone
Crush - Pressure	Crushing on growing bone
Comminuted	Bone broken into more than two fragments
Penetrating	Partial or complete, on bone cortex
Transverse	Force in a line perpendicular to the longitudinal axis of the bone
Direct trauma	**break at point of impact**
Avulsion	Broken due to tension at a tendon or ligament attachment
Burst	Mainly due to vertical compression
Comminuted	'T' or 'Y' shape in broken bone due o force from different directions
Greenstick	Incomplete fracture due to rotational or angular force
Impacted	Ends of the bone are driven into each other
Oblique	Angular or rotational force on the long axis
Spiral	Longitudinal or rotational force on the long axis
Torus	Impaction; buckling of the bone due to longitudinal compression
Other trauma	
Secondary or pathological	Secondary fracture of a weakened bone due to a disease
Stress or fatigue	owing to repetitive force

Four main causes of injuries are defined: accidents, interpersonal violence, pathological fracture, and stress fracture. How susceptible a bone is to an injury depends upon the ability of the bone to withstand the blow. Intrinsic factors, including density, elasticity, and plasticity, play an important part (Pinhasi and Mays, 2008). The mechanism responsible for bone fractures is mostly blunt force trauma caused by either external pressure or internal loading forces over a wider area of the affected bone and leading to plastic deformation resulting in soft-tissue failure (Lovell and Grauer, 2018). The definition of sharp force trauma refers to the application of force resulting in a separation or division of the skin and the soft-tissue underneath. The force applied is limited to a specific area of the bone with rather low velocity in contrast to blunt force trauma. Many different types of injuries result from stab wounds, lacerations, cutting and penetrating injuries, incised wounds, puncture wounds, chopping wounds, perforating, slash wounds and sharp force injuries. All of the listed injuries can be sustained by a sharp edge or pointed object. Major limitations with sharp force injuries to the skeleton exist, as most of these injuries involve only soft-tissues and are therefore not preserved in the osteological material (Vanezis, 2021; Lovell and Grauer, 2018).

3.2.2 Healing of fractures and traumas

Bones are exceptional in their ability to regenerate after adulthood has been reached in contrast to other soft-tissues, which only heal through the formation of connective scar soft-tissue (Giannoudis et al., 2007). The healing of an injury begins immediately after it occurred, but the process varies depending on the affected bone, the type of fracture, treatment and the stabilisation of the fractured fragments, the age of the individual, the presence of infection, blood supply, and the diet of the person (Waldron, 2020; Roberts, 2000; Lovell and Grauer, 2018). Chronic diseases may alter the healing process additionally (Bennike, 2008). Table 2 summarises the activities of the three stages of healing in long bones and their characteristic traits (Lovell and Grauer, 2018). The process of healing starts with the inflammatory stage at the cellular level, which can last around 72 hours. This is an immediate reaction with bleeding to the fracture and increased cell division leading to a haematoma. This process calms down after a few days and is limited to the injured area. The broken bone ends themselves are dead and play a passive role during the bridging (McKibbin, 1978; Lovell and Grauer, 2018). The next phase is the reparative phase, which begins around the second day and lasts until two weeks. During the healing process, a "primary callus" response develops leading to the transformation of the bone (McKibbin, 1978). The haematoma gets resorbed and woven bone formation starts through the mineralisation of osteoid (Lovell and Grauer, 2018). This process can vary in how much new bone is formed depending on the affected bone, while the bone removal and replacement occur simultaneously. During this phase (i.e. metabolic phase), the immature bone of the callus is replaced by mature lamellar bone (A. L. Grauer, 2012). The gradual remodelling phase starts in the middle of the reparative phase and can last up to seven years. The initial bone integrity gets restored through continues bone formation. The dead bone may be resorbed but not necessarily, depending on mechanical factors (Waldron, 2020; Machado, 2013; Lovell and Grauer, 2018).

Four different types of soft-tissues influence the process of fracture healing: the bone marrow, surrounding the undifferentiated fascial soft-tissue, the periosteum, and the cortical bone (Marongiu et al., 2020). Through the high activity of osteoblasts and osteoclasts, the bone is remodelled to its anatomical shape (Roberts, 2000). If a fracture has not been stabilised or has been poorly stabilised, more callus must be formed to compensate (Czarnetzki, 1996). The bones are continuously remodelling themselves to withstand any kind of physical activity or stress (Romani et al., 2002). The healing process of a long bone fracture may heal differently depending on the complexity of the fracture pattern (single/multi-fragmented), the bio-mechanical environment at the fracture site, and the blood supply (Marongiu et al., 2020). Long bones heal slower than cancellous bones, and upper extremity fractures may heal twice as fast as lower extremity fractures (Lovell and Grauer, 2018).

The healing mechanism is very complex and is not fully understood on a molecular basis. However, it is clear that every fracture healing is unique and the timing and event of repairing the endochronral and intramembranous bone formation depends on the situation (Einhorn, 2005).

Table 2: A summary of fracture healing processes in long bones (after Buckwalter and Einhorn, 2006; Schenk, 2003; Shantz et al., 2015 Judd and Redfern, 2012; modified from Lovell and Grauer, 2018)

Stage 1 - Cellular
soft-tissue destruction and haematoma formation within 25 h
blood clots form and fractured bone ends **die**
periosteum is stripped
not visible on dry bone
inflammation and cellular proliferation: within 48h up to 3-4 weeks
osteoblasts form a bond of osteoid around fragments
osteoid forms on periosteal and endosteal surface
bridging of fracture
not visible on dry bone
callus formation: at 2-3 weeks, continues until the fracture is bridged at around 8-9 weeks
mineralization of osteoid
callus forms
visible on dry bone
Stage 2 - Metabolic
consolidation: variable from weeks to months
mature lamellar bone forms from callus precursor
afterwards the fracture ends unite
Stage 3 - Mechanical
remodeling: over years
follows lines of biomechanical stress
affected area usually permanently marked

The visibility of healing in the dry bone is possible after callus formation around one to three weeks after the injury was sustained (Lovell and Grauer, 2018). In an archaeological context, the observed fractures are often healed, indicating that the bone has already undergone the first two phases of the healing process. Depending on the circumstances, fractures may heal differently, but the availability of treatment will influence the outcome. The stage of healing and the influences around it can shed light on a person's life. For example, degenerative joint alterations, and trauma can suggest certain habitual activities, warfare, labour, occupational hazards, and aspects of subsistence strategy (Friedl, 2011).

4 Aims and hypotheses

4.1 Aims

First, the aim of this thesis is to examine the long bones of the adult population (age at death > 17 years) of the cemetery of Mödling - An der Goldenen Stiege from the 7th to the 8th-century AD for trauma-related injuries, i.e., fractures and traumas, and their state of preservation. Definitions of trauma and fractures, as well as ante/peri/postmortem characteristics and types of injuries are established before the examination. The frequency of fractures and trauma by sex, age at death, affected long bone, Avar period, and upper/lower extremity will be examined to understand the osteological remains studied. This information will be obtained as part of the ERC-funded Histo-Genes 2020 research project and supervised by Dr. Sabine Eggers and discussed with Dr. Margit Berner and Dr. Doris Pany-Kucera from the Natural History Museum Vienna (NHM). Frequencies of injuries will be calculated to recognise trends of injuries among groups of sex, age at death, and affected long bone and tested for differences based on the previously established hypotheses. To test whether there are significant differences between sex, multiple injuries between the sexes, the three age at death groups, and the extremities in relation to injuries of the long bones, chi-square tests will be calculated for all injuries together. The obtained results will be put into context and comparisons of injury prevalence between other cemeteries associated with the Avar period in the Carpathian Basin will be drawn. Related aspects of how these injuries might have been sustained (accidental vs. violence), who was affected, which types of traumas occurred, their social, cultural and funerary aspects and meaning, and the state of care and treatment will be discussed. These aspects affecting the life of individuals assigned to the Avars should contribute to the knowledge about life in the Early Middles Ages.

4.2 Hypotheses

The following hypotheses are, first, derived from contextual literature on 7th and 8th-century Avar burials in the Carpathian Basin, with a focus on Austrian burials and the prevalence of injuries, (Pany-Kucera and Wiltschke-Schrotta, 2017; Daim and Lippert, 1984; Pany-Kucera and Wiltschke-Schrotta, 2023; Wiltschke-Schrotta and Stadler, 2005; Daim, 1984; Großschmidt, 1990) and, second, the following references serve as the basis for the hypotheses on the distribution of injuries with regards to sex, multiple injuries, age at death, and extremities.

Hypothesis 1: In general, more aggressive behaviour is observed in males than in females (Eagly and Steffen, 1986; S. Novak, 2017). Further, males are more likely to take risks in everyday situations than females (Pawlowski et al., 2008). Both behaviours can lead to more accidents but also interpersonal violence. It has been found that males often take part in more hazardous occupations such as agriculture, forestry, or construction (Lovell, 1997). Hence, hypothesis 1 states: the prevalence of injuries altogether is higher in males than females buried in the cemetery of Mödling - An der Goldenen Stiege from the Avar period.

Hypothesis 2: Similarly, the same aggressive and risk-taking behaviour leads to the assumption that males exhibit more multiple injuries (Eagly and Steffen, 1986; S. Novak, 2017; Pawlowski et al., 2008). This is supported by studies about bone traumas that have recorded that multiple injuries in general occur more often in males (M. Novak and Šlaus, 2010; Šlaus et al., 2012). Hence, hypothesis 2 states: the prevalence of multiple injuries altogether is higher in males than females buried in the cemetery of Mödling - An der Goldenen Stiege from the Avar period.

Hypothesis 3: If a person lives a longer life, they are more likely to accumulate injuries with increasing age (Judd and Redfern, 2012; Roberts and Manchester, 2010). Furthermore, older individuals, especially older females, are more prone to injuries secondary to aging due to the deterioration of bone microstructure and the loss of bone mass through diseases, such as osteoporosis (Bennike, 2008; Cawthon, 2011; Roberts and Manchester, 2010). Hence, hypothesis 3 states: the prevalence of injuries altogether is higher in older individuals than in younger individuals in the cemetery of Mödling - An der Goldenen Stiege from the Avar period.

Hypothesis 4: The anatomical distribution of interpersonal violence injuries mainly affects the upper extremity (after the head and face) (Brink et al., 1998). Palaeopathological studies suggest that the upper extremity, mainly the ulna, is more affected by interpersonal violence while the lower extremity is more affected by accidental injuries such as falls (M. Novak and Šlaus, 2010; Šlaus et al., 2012). But, the radius and clavicula also often break during a fall (Mays, 2006; Judd and Redfern, 2012). Hence, hypothesis 4 states: the prevalence of injuries altogether is higher on the upper extremity (clavicula, humerus, radius, ulna) than on the lower extremity (femur, tibia, fibula) in the cemetery of Mödling - An der Goldenen Stiege from the Avar period.

5 Material - human remains

The osteological remains analysed originated from excavations of a cemetery dating in the 7th and 8th century in Mödling - An der Goldenen Stiege in Lower Austria. Mödling was part of the border of the Avar empire of the Danube. Mödling - An der Goldenen Stiege (Figure 4) lies near the Eastern hillside of the Vienna Woods and on the edge of the Northeastern foothills of the Anninger hill. The area of "An der Goldenen Stiege" is located west of the town Mödling and is limited by the Frauenstein Eastern slope, and in the north and east by topographic steps. To the south, the property borders a valley (Schwammenhöfer, 1976). Nearby lies a small river called the Mödling, south of the cemetery (Winter, 1994). The cemetery itself lies on the Eastern slope of the Frauenstein hill and extends about 80m x 80m on a terrace-like but levelled area. The area is 20 m above the

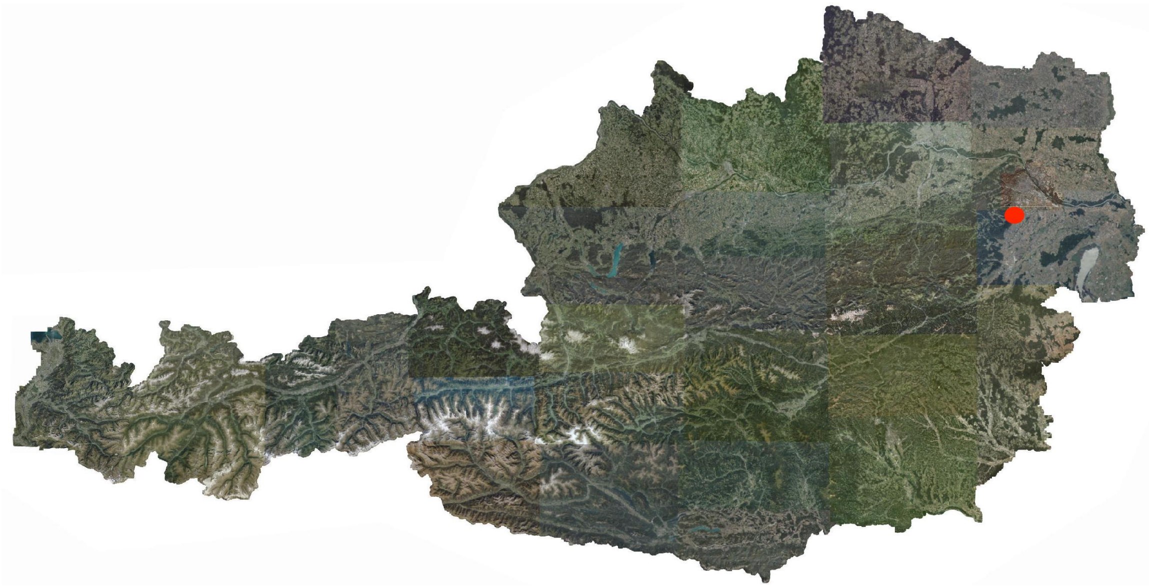

Figure 4: The location of the cemetery of Mödling - An der Goldenen Stiege (Source: https://www.basemap.at)

level of the current city of Mödling. The conditions of the surrounding soil were rather unfavourable in terms of preservation of skeletal remains with intense soil cultivation, which led to the destruction of many surface-level graves. Some of the skeletal material were poorly preserved, mostly due to disturbance and ransacking. The sediment consisted of a 0.5 to 1 m thick humus layer and was followed by sandy loam with calcareous rock fragments (Marhold, 1977).

The site first received attention in 1911 after a grave with a skeleton, a pot, an iron ring, and an iron knife were found. Excavations started in 1967 after more burials were discovered due to construction on the site. First, Clemens Eibner and Karl Matzner of the Mödling Museum initiated the excavations, and more graves came to light through the "Fundbergdienst" of the Austrian Working Group for Prehistory and Early History. In 1971, the excavations were taken over by Hermann and Lotte Schwammenhöfer and continued until 1973. Over 500 graves were discovered and 491 of them were attributed archaeologically to the Avar age (Distelberger, 1999). In the cemetery of Mödling, over 500 persons were buried over a period of around 150 years.

Next to the cemetery, settlement remains of a late Neolithic, Bronze Age, and Iron Age settlement as well as cremations from the Hallstatt period were located. However, no settlement remains from the Avar period were detected. The buried individuals were laid down in a supine position and mostly orientated from east to west. Almost every grave contained animal bones and pottery. It should be noted that no horse burials were found in Mödling but few isolated horse bones were found in graves 10 and 140. Over 4000 objects were collected from the archaeological context of the graves. Iron finds were restored by Hermann Schwammenhöfer and pottery by the Museum Mödling. The finds of Mödling - An der Goldenen Stiege were kept in the Museum Mödling, and the human remains were handed over to the Anthropology Department of the Natural History Museum in Vienna (NHM). The grave drawings were made by Leo Leitner, Gabor Kovacs-Gombos, Franz Siegmeth, Karl Matzner and Anton Distelberger (Daim, 1976; Eibner and Matzner, 1966; Schwammenhöfer and Schwammenhöfer, 1971; Schwammenhöfer and Schwammenhöfer, 1972; Matzner and Schwammenhöfer, 1973; Distelberger, 2004; Marhold, 1977; Schwammenhöfer, 1976; Distelberger, 1999). The list of animal bones was prepared by Alfred Galik and its publication is pending.

The osteological material of Mödling - An der Goldenen Stiege was systematically recorded using methods adapted by members of the NHM and the ERC funded HistoGenes project. This included the state of preservation, injury recording, and fracture and trauma frequency calculations based on the international literature.

5.1 Archaeological contextualisation

The cemetery of Mödling - An der Goldenen Stiege has been archaeologically dated and can be divided into several groups based on the "internal chronology" (Distelberger, 1999). The first group was dated to the Middle Avar time (630 AD) starting with the second half of the 7th century. Dating was based on the features of earrings (with and without pompoms) and the way belt sets were produced. The second group was dated as the first Late Avar time (680 AD) group and was recognised by the appearance of bronze casting for belt sets. The most extensive find horizon was represented by the second Late Avar phase (720 AD) with a variety of forms continuing to the third Late Avar phase (Daim, 1976). The cemetery of Mödling - An der Goldenen Stiege was recognised for the noticeable continuation starting with the Middle Avar period (Mödling, 1977; Daim, 1976; Distelberger, 1999).

Another way of dating graves was pottery. In the Middle Avar period, the pottery presented tall, slender and hand-formed vessels with a raised rim, which changed later to cup-shaped vessels with a protruding rim. During the advanced stages of the Late Avar period, the rim of the pottery turned shorter and was partially attached to the shoulder of the pot (Daim, 1994). The archaeological dating was carried out by Peter Stadler and Falko Daim. During the 7th and 8th century, the material culture in the Austrian find area of the Carpathian Basin presented a clear continuity. Per a commonly used absolute chronology model, the Early Avar period corresponds to the first half of the 7th century, the Middle Avar period corresponds to the second half of the 7th century, and the Late Avar period corresponds to the 8th century (Distelberger, 2004).

The chronology of the cemetery of Mödling - An der Goldenen Stiege suggests that the cemetery had been used for a considerable period of time, starting in the Middle Avar period I (630-655 AD) to the Late Avar period III (760-822 AD). The Avar periods with their associated time and abbreviations were adopted (Stadler, 2010) and combined into three periods. The Avar periods used in this thesis are shown in Table 3.

Table 3: Avar periods adapted and combined from Stadler (2010)

Period	Abbrevation	Time span
Middle Avar	MA	630-680 AD
Late Avar	SPA	680-760 AD
Late Avar I	SPA I	760-822 AD

Supine body burial was the preferred method of burial along with grave goods, including pots, animal bones, arrow heads, spindle whorls, knives, and jewellery (Distelberger, 1999). The grave goods consisted of more than 4000 artefacts, reflecting various finds characteristic of cemeteries from the Avar period. During the period of use of this cemetery, changes in the archaeological record can be observed, from richer graves with various grave goods to fewer grave goods and reburial in a pre-existing grave, possibly reflecting the uncertainty and political changes in the last phase of the Avar period (Distelberger, 1999).

Although more than 100,000 Avar graves have been excavated (Daim, 1984), only about 600 Avar settlements have been found, most of which are located in Southeastern Hungary. In regards to structures used for settlements, the Avars used sunken-featured buildings, i.e., structures built below the ground level, as rectangular pits. Within these buildings, near ovens, or as a basis for ground-level building, post-holes have been found. In some cases, round features have been found, which were interpreted as ' "yurts" by the excavators. Inside those buildings, ovens were placed most likely used for heating and backing. For water resources, wells in the form of rectangular timber-lined structures have been found in the last few years. Pits of various shapes have been excavated with different fillings, mostly representing storage for food, but also ditches used for drainage. Avar villages also show evidence of occupations with structures relating either to iron work, or pottery production (Herold, 2018). These findings suggest an at least party sedentary lifestyle, which supports the fact that the Early Avars changed from a nomad-lifestyle with military campaigns to a more settled life based on agriculture and animal husbandry in the Carpathian Basin (Pohl, 2018).

6 Methods

6.1 Preservation

The long bones (clavicula, humerus, radius, ulna, femur, tibia and fibula) were examined macroscopically. Each individual (n = 298, after exclusion n = 265) was displayed for examination and side determination (right/left). The state of preservation was recorded for every long bone and divided into five segments: "1" proximal end of the bone, "2" proximal end of the shaft, "3" middle of the shaft, "4" distal end of the shaft, "5" distal end of the bone – with an exception for the clavicula, which had only three segments (Figure 5). Each segment of the bone was evaluated, and the state of preservation was classified as 0 if nothing was preserved, 1 if 1 to 50% was preserved and 2 if more than 50% was present. This method of recording the state of preservation was established for the HistoGenes project in the Natural History Museum Vienna. Systematic recording refers to consistent and thorough data collection with a specific focus, i.e., preservation as well as fractures and trauma in this thesis (Stodder, 2012).

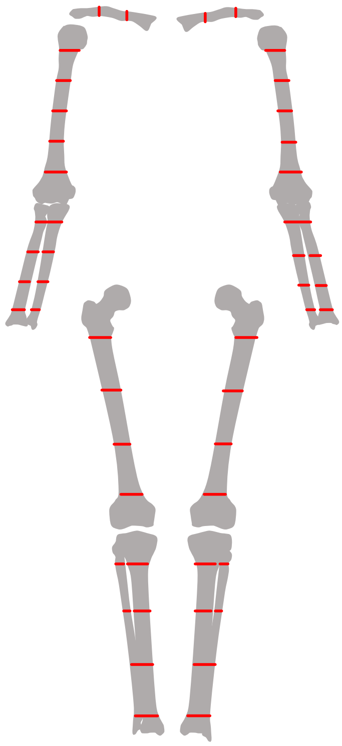

Figure 5: Division of long bone segments: clavicula with 3 segments, humerus, ulna, radius, femur, tibia and fibula with 5 segments. The red lines show the division between the proximal end, the shaft with 1 or 3 segments and the distal end (made by A.Wagner)

6.2 Sex estimation

The sex estimation was done by Karin Wiltschke-Schrotta, Gabriele Bernhofer and Sonja Navratil at the Anthropological Department of the Natural History Museum Vienna and modified for this thesis. The macroscopic assessment was carried out on the basis of the work sheet attached in the appendix (Wiltschke-Schrotta, n.d.).

The features of the long bones included robusticity of femur and humerus. All the mentioned characteristic features were graded between +2 (definitely male) and -2 (definitely female) and weighted according to their expression. The work of Ferembach was mainly used for the sex estimation (Ferembach et al., 1979). In the framework in the HistoGenes project 2020 the individuals of Mödling were genetically sexed and the results are mainly in agreement with the sex estimation presented here.

The sex categories were originally characterised as ”m”, ”f’, ”m?”, ”f?”, ”indeterminate” as well as ”m/archaeological female”. The individuals with ”m/archaeological female” were categorised as ”m” for male. The individuals with ”m?” and ”f?” were determined as male or female each. In total, the sex categories were combined to male, female and indifferent.

6.3 Age estimation

Skeletons from individuals who died at the age of 17 years onwards were included in this study. The age estimation was carried out by Karin Wiltschke-Schrotta, Gabriele Bernhofer and Sonja Navratil at the Anthropological Department of the Natural History Museum Vienna and modified for this thesis (Wiltschke-Schrotta, n.d.).

The methods used for age at death estimation of adults were based on tooth abrasion, fusion of endo- and ectocranial sutures, changes at the pubic symphysis, epiphyseal fusion and changes at the sternal joint surface of the clavicle (Szilvássy, 1988).

Originally, the age classifications ”adult”, ”adult-mature”, ”mature”, ”mature-senile”, and ”senile” were determined as well as ”adult-senile” in case of no possible age determination. These age at death spans were combined herein based on the mean age to young adult (17–34), middle adult (35–49) and old adult (>50) following Buikstra and Ubelaker, 1994. The age at death categories are presented in Table 4. Individuals classified earlier as ”adult-senile” or with an age at death spanning over 30 years were excluded from this thesis as these individuals would not be representative of a certain age group. A total of 33 of the 298 individuals were excluded, resulting in a total of 265 individuals examined.

Table 4: Comparison of age at death categories

Original by Karin Wiltschke-Schrotta	Categories used in this thesis
adult	young adult (17-34)
adult-mature	middle adult (35-49)
mature	old adult (>50)
mature-senile	
senile	
adult-senile	

6.4 Macroscopic recording

A protocol for data recording was prepared and adopted (Ubelaker, 1999; Lovejoy and Heiple, 1981; Roberts and Manchester, 2010). The skeletons were inspected for the presence of fractures and/or trauma. Trauma can be defined in a number of ways, but is traditionally understood to refer to damage to living soft-tissue caused by external forces or mechanisms both accidental or intentional (Adams and Hamblen, 1991; Lovell, 1997). More specifically, skeletal trauma refers to the disruption of bone integrity (Ortner, 2003a; Merbs, 1989). If an injury was present, it was recorded in association to the bone segment as well as the side and documented photographically. Further examinations by x-ray documentation were also carried out. To evaluate the mechanism and the complications arosen by the injury to the individual's health, the associated bones were examined as well, if present. In the case of injuries, distinctions for ante/peri/postmortem injuries were made based on the following criteria presented in Table 5.

Table 5: Characteristics of ante/peri/postmortem injuries (after Sauer, 1998; Lovell, 1997)

Timing of injury	Characteristics
Antemortem	before death
	signs of healing
Perimortem	antemortem period (up to 3 weeks) or postmortem period (fresh bone)
	no evidence of healing
	uniform stains from contact with soil, vegetation, water
	incomplete, spiral, compressed, and depressed fractures
	oblique angles on fracture edges
	patterns of concentric circular, stellate, or radiating fracture lines
Postmortem	after death
	result in smaller fragments
	non-uniform colouration with light-coloured edges

Additionally, the causes of injury, whether accidental or violent, were researched in the literature and described to use as the basis for interpretation. Definitions of violence speak to the intent to hurt someone. The only way violence is visible on skeletal remains is by causing an injury through physical force. However, violence can also manifest itself in the form of emotional, psychological, or sexual violence and can occur only on an individual level or be organised and socially sanctioned (Martin and Harrod, 2015). Demonstrations of interpersonal and intentional violence can be represented directly, in the skeletal remains, and indirectly in the burial context of a person. Well-known signs for interpersonal violence in the bioarchaeological context include the "parry fracture", traumas and dents on the skull, and projectile point wounds in the skeletal remains. Violence that resulted in the death of a person, or perimortem injuries, may be represented in the burial context with atypical signs of careless placement or possibly even a mass grave (Ortner, 2003b). The "parry fracture" as an indicator for violence remains problematic (see discussion) and has to present the following criteria after Judd (2008): located on the ulna, no radial involvement, a transverse fracture line, the fracture has to be located below the middle of the shaft, and minor unalignment less 10 degrees or horizontal apposition from the diaphysis (more than 50%). Another criterion that a parry fracture must meet is the fact that it was caused by a direct blow, which leads to the problem at hand (Judd, 2008). Even if an ulna shaft fracture meets the mentioned criteria, the ultimate mechanism of an injury remains unknown. It is impossible to know the circumstances of how the injury occurred, what situation the person was in, or how the people behaved.

The definition of an accident can be interpreted in a number of ways, but generally implies a lack of intent. Another way of seeing an accident may also be that a human error was responsible, either the persons themselves, or an external party (Robertson, 2018). When a fracture is associated with an accident, such as a fall, the risk of fracture in any given situation depends in part on the bones (Bennike, 2008). A very common reason for accidents is falling. The definition of a fall is an unexpected loss of balance that causes one to come on the ground (Nordstrom et al., 1996). A fatal fall is defined as a fall from a height of more than 3 metres. A fall from a lower height means a fall free of obstructions and only under the influence of gravity. Low falls can result in blunt force trauma. Studies showed that almost all skeletal elements are susceptible to fractures when falling (Rowbotham et al., 2018). A wide range of fracture morphologies can occur due to a fall. Low free falls rarely result in bilateral fractures, and when they do, they are more likely due to greater heights (1.5-3 m) (Rowbotham et al., 2018; Rowbotham et al., 2019).

The presence and state of healing was recorded with the following stages: healed, healing, unhealed and further information about mal-union or non-union was collected. Non-union refers to a fracture, which did not heal and a mal-union is characterised as malaligned healed fracture (Waldron, 2020). Another complication following a fracture may be shortening of the bone, which is caused by substantial angulation, crushing, overlap or gross bone loss. Shortened bone has a great impact on the weight-bearing lower extremity. To determine the degree of shortening, the normal contralateral bone is used as reference. Some clinical practitioners argue that up to 20 mm of bone shortening may be tolerable but the degree of shortening and its potential impact depends on the bone itself (Waldron, 2020; Lovell, 1997). The affected long bones were measured with an osteometric board to document the maximum length of the bone (if possible) in order to assess bone shortening. In the case of an injury on the surface of the compact bone, which did not affect the length of the bone, the area involved was measured with a caliper. In addition, the bones associated with the injured bone were examined for pathological changes resulting from the injury to detect signs of use such as entheses (Benjamin et al., 2002; Claudepierre and Voisin, 2005).

As this study also includes other traumatic occurrences besides fractures, periosteal reactions, signs of inflammation and other pathological lesions were recorded as well. In order to better understand the full picture of the multiple injured individuals, the analyses of the skull and the rest of the postcranium were included in the discussion. The bones were recorded in the same manner as the long bones but were not only recorded by the author but also the experienced members of the Anthropology Department of the Natural History Museum Vienna (NHM), mainly Dr. Margit Berner and Dr. Doris Pany-Kucera, and the HistoGenes project.

6.5 Radiographic recording

The long bones with suspected fractures or traumas were radiographed from at least two different angles. The x-ray equipment used was provided by the Anthropology Department of the Natural History Museum Vienna (NHM). The radiographic unit used was X-ray facility VSXR02, serial number 2020120, Med. Vertriebs- und Service GmbH (Röntgen: Gierth X-Ray int. GmbH, Modell HF200A+Gen2, Ser.Nr. 41826. Detektor Varex Imaging Technik, Refä 95510606, Ser. Nr. 420; KV: 80, μ As1200). Radiographs helped to determine the type of fracture, the state of healing, and the degree of displacement, if any.

The measurement of the angulation of the fractured bones was performed with ImageJ on the x-ray images. The direction and degree of displacement were measured with the angulation tool with three points. The angulation tool was placed at the center of the proximal end of the bone, then at the fracture line, and finally at the center of the distal end of the bone. The measurement of angulation was problematic due to the highly subjective method of measurement. Depending on the angle of the x-ray image and the subjective placement with the angulation tool, the results may vary. The results differ between measurements and are subjective to the person who measured. Therefore, all angulation measurements are presented +/- 2° (A. Grauer and Roberts, 1996; Lovell, 1997; Roberts, 1988).

6.6 Statistical calculations

Statistical analyses included the calculation of frequency distributions of injuries of the individuals included in this study (n = 265). Individuals without long bones, with an age at death span greater than 30 years, and those who could not be assessed were excluded (n = 33). The Avar periods were combined to Middle Avar period (MA), Late Avar period (SPA), Late Avar I period (SPA I) to allow a better comparability. The calculation of the prevalence of injuries was performed by n individuals with injuries / N individuals in total. The true prevalence rate calculation was carried out by skeletal elements for each segment (n long bone segment with injuries / N bone segment in total). For the true prevalence rate, bone segments were included if they had the preservation status 1 or 2 assigned. Hypothesis 1, 2, and 4 were tested with a Fisher's Exact Test, and Hypothesis 3 was tested with the Chi-Squared Test. But the test between younger individuals (young adults) and older individuals (middle and old adults) in Hypothesis 3 was tested with a Fisher's Exact Test as well. The statistical significance was defined by probability levels of $p < 0.05$. The data was recorded with Microsoft-Excel. The statistical analysis was done with R Version 4.2.0.

7 Results

7.1 Preservation

The long bones were separated in five segments with the proximal end (1), three shaft segments (2, 3 and 4) and the distal end (5) with the exception of the clavicula, were only three segments were separated. On examination, it was clear that the shaft of the long bones in particular was preserved, but fewer joints at the proximal or distal ends. The long bones in this cemetery were heavily eroded, and the original surface was often not completely preserved. The preservation of the skeletal remains was poor in many cases due to taphonomic changes, such as erosion, water, and the results of the rescue excavation. Additionally, in some cases bones were disturbed in their grave due to grave robberies and other disturbances, which lead to rearrangements in the grave and more susceptibility to damage to the bone.

In Table 6, the state of preservation for each long bone was separated by side (left/right), by segment (1-5) and by preservation status 0, 1, and 2. In total, 2992 long bones (80.6%) were present, and 718 long bones (19.4%) were not available. All seven long bones on both sides showed a similar trend, with preservation state 2 assigned mostly to the shafts (segments 2, 3, and 4), while the proximal end (1) and distal end (5) had mostly preservation state 0, except for the clavicle and tibia, where the ends of the bones were more available. Preservation state 1 was least pronounced in all long bones on both sides, meaning that either more than 50% of the bone was present or nothing was available at all. Particularly well preserved long bones were the clavicle and femur, where preservation state 2 was assigned most frequently in all segments. Not well preserved was the fibula, where both the proximal (left 86.6%, right 86.4%) and distal ends (left 72.1%, right 69.4%) of the bone were mostly absent on both sides. However, the shafts of the fibula were not particularly well preserved either, with preservation status 0 accounting for almost half of the assigned preservation status on both sides. The radius and ulna were similar in their state of preservation, with the proximal and distal ends missing in half of the cases. Overall, however, the radius was slightly better preserved.

Table 6: Preservation of all long bones separated by side (left/right), segments (1-5, clavicle had only 3 segments, which correspond to segments 1, 3 and 5, see Figure 5) and preservation status (0, 1 and 2)

			Clavicula	Humerus	Radius	Ulna	Femur	Tibia	Fibula
L	1	0	67 (25.3%)	156 (58.9%)	152 (57.4%)	123 (46.4%)	85 (32.1%)	91 (34.3%)	230 (86.8%)
		1	33 (12.5%)	24 (9.1%)	33 (12.5%)	62 (23.4%)	62 (23.4%)	38 (14.3%)	8 (3.0%)
		2	165 (62.3%)	85 (32.1%)	80 (30.2%)	80 (30.2%)	118 (44.5%)	136 (51.3%)	27 (10.2%)
	2	0	-	45 (17.0%)	77 (29.1%)	81 (30.6%)	16 (6.0%)	22 (8.3%)	128 (48.3%)
		1	-	28 (10.6%)	32 (12.1%)	31 (11.7%)	10 (3.8%)	29 (10.9%)	43 (16.2%)
		2	-	192 (72.5%)	156 (58.9%)	153 (57.7%)	239 (90.2%)	214 (80.8%)	94 (35.5%)
	3	0	63 (23.8%)	38 (14.3%)	71 (26.8%)	82 (30.9%)	13 (4.9%)	19 (7.2%)	116 (43.8%)
		1	7 (2.6%)	12 (4.5%)	13 (4.9%)	22 (8.3%)	6 (2.3%)	9 (3.4%)	21 (7.9%)
		2	195 (73.6%)	215 (81.1%)	181 (68.3%)	161 (60.8%)	246 (92.8%)	237 (89.4%)	128 (48.3%)
	4	0	-	41 (15.5%)	80 (30.2%)	104 (39.2%)	14 (5.3%)	23 (8.7%)	117 (44.2%)
		1	-	19 (7.2%)	32 (12.1%)	39 (14.7%)	15 (5.7%)	16 (6.0%)	49 (18.5%)
		2	-	205 (77.4%)	153 (57.7%)	122 (46.0%)	236 (89.1%)	226 (85.3%)	99 (37.4%)
	5	0	74 (27.9%)	138 (52.1%)	142 (53.6%)	183 (69.1%)	95 (35.8%)	82 (30.9%)	191 (72.1%)
		1	30 (11.3%)	29 (10.9%)	20 (7.5%)	14 (5.3%)	48 (18.1%)	33 (12.5%)	14 (5.3%)
		2	161 (60.8%)	98 (37.0%)	103 (38.9%)	68 (25.7%)	122 (46.0%)	150 (56.6%)	60 (22.6%)
R	1	0	72 (27.2%)	151 (57.0%)	143 (54.0%)	114 (43.0%)	98 (37.0%)	100 (37.7%)	229 (86.4%)
		1	28 (10.6%)	18 (6.8%)	30 (11.3%)	68 (25.7%)	56 (21.1%)	47 (17.7%)	8 (3.0%)
		2	165 (62.3%)	96 (36.2%)	92 (34.7%)	83 (31.3%)	111 (41.9%)	118 (44.5%)	28 (10.6%)
	2	0	-	39 (14.7%)	70 (26.4%)	73 (27.5%)	24 (9.1%)	26 (9.8%)	109 (41.1%)
		1	-	21 (7.9%)	29 (10.9%)	29 (10.9%)	9 (3.4%)	29 (10.9%)	62 (23.4%)
		2	-	205 (77.4%)	166 (62.6%)	163 (61.5%)	232 (87.5%)	210 (79.2%)	94 (35.5%)
	3	0	60 (22.6%)	29 (10.9%)	62 (23.4%)	78 (29.4%)	21 (7.9%)	25 (9.4%)	99 (37.4%)
		1	4 (1.5%)	7 (2.6%)	14 (5.3%)	17 (6.4%)	8 (3.0%)	7 (2.6%)	23 (8.7%)
		2	201 (75.8%)	229 (86.4%)	189 (71.3%)	170 (64.2%)	236 (89.1%)	233 (87.9%)	143 (54.0%)
	4	0	-	29 (10.9%)	66 (24.9%)	100 (37.7%)	21 (7.9%)	28 (10.6%)	105 (39.6%)
		1	-	11 (4.2%)	27 (10.2%)	33 (12.5%)	21 (7.9%)	19 (7.2%)	51 (19.2%)
		2	-	225 (84.9%)	172 (64.9%)	132 (49.8%)	223 (84.2%)	218 (82.3%)	109 (41.1%)
	5	0	64 (24.2%)	133 (50.2%)	137 (51.7%)	183 (69.1%)	93 (35.1%)	80 (30.2%)	184 (69.4%)
		1	29 (10.9%)	37 (14.0%)	20 (7.5%)	7 (2.6%)	47 (17.7%)	35 (13.2%)	11 (4.2%)
		2	172 (64.9%)	95 (35.8%)	108 (40.8%)	75 (28.3%)	125 (47.2%)	150 (56.6%)	70 (26.4%)

Figure 6 shows the state of preservation of the proximal end, the shaft (segment 2, 3 and 4), and the distal end with the status assigned to each. For this figure, the shaft segments (2, 3, and 4) were grouped together instead of considering each bone segment individually because their state of preservation was very similar. The shafts of the long bones were assigned preservation status 2 in most cases. Figure 6 shows the same distribution as Table 6, where 1 was the least assigned in all segments and where both the proximal and distal ends have a similar distribution with preservation state 0 being the most common. This result suggests that the shafts were more likely to be well preserved compared to the proximal and distal ends of the long bones due to taphonomic forces and the fact that the joints of the long bones tend to be composed of spongy bone to a higher degree and dissolve more easily. As mentioned in the chapter Material, some of the skeletal remains were exposed to water damage but also grave disturbances, which lead to extensive rearrangements of the bones and possibly more damage to the bones.

A significantly higher ($\chi^2 = 1.27$, df = 1, p = 0.005) preservation of the lower extremity (femur, tibia, fibula) then the upper extremity (clavicula, humerus, radius, ulna) was found. In total 79% of the lower extremity long bones were available compared to 73% of the upper extremity long bones.

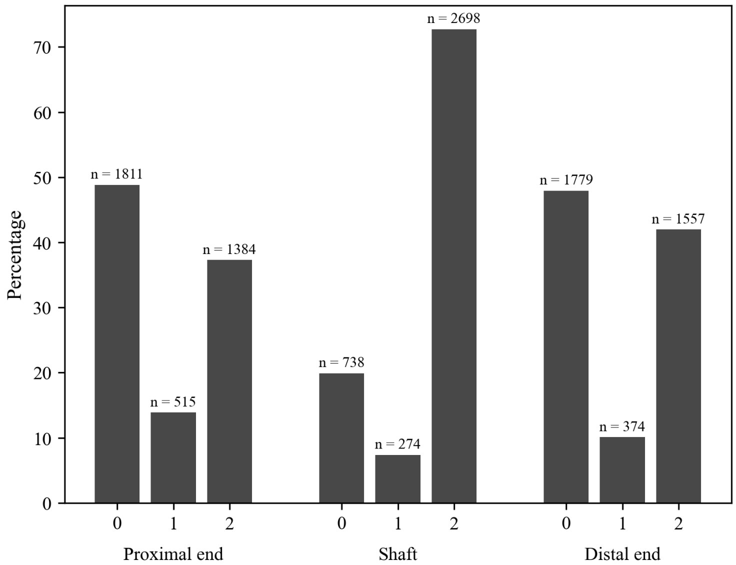

Figure 6: Distribution of the state of preservation (0 = no bone available, 1 = < 50%, 2 = > 50%) divided by proximal end, shaft and distal end of the long bones

Overall, the long bones from Mödling - An der Goldenen Stiege were well preserved in terms of the shaft of the long bone, but the joints were often missing. This result may have led to a bias in the recording of injuries, as the joints and thus specific injuries such as dislocations and cracks (for example tibia plateau fractures) were not represented. The upper extremity was less well preserved than the lower, meaning that possibly fewer injuries could be recorded.

7.2 Palaeodemographic aspects

Originally, 298 individuals were examined for this study, but only 265 were included in the analyses. Individuals with no precise age at death ("adult-senilis") or an estimated age at death spanning over more than 30 years and individuals with no long bones (n = 33, 11.7%) were excluded. Out of the 265 individuals, 142 were classified as male (53.6%) and 118 (44.5%) as female. Because of insufficient assessable features, five individuals were categorised as indifferent (1.9%) and were excluded from comparisons between the sexes. The sex distribution was significantly different, with more males being buried in the cemetery than females (χ^2 = 1.45, df = 2, p = 0.044). The sex distribution of the individuals included in this study is shown in Figure 7.

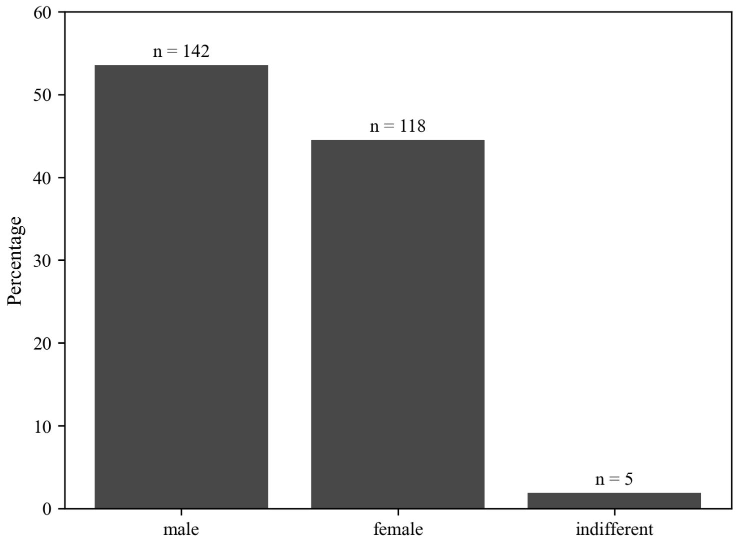

Figure 7: Distribution of sex with individuals divided into male, female, and indifferent

For this thesis, three age categories were selected following Buikstra and Ubelaker (1994). The young adults (n = 122) accounted for 46.0% of the individuals, the middle adults for 29.4% (n = 78), and old adults for 24.5% (n = 65). Therefore, almost twice as many young adults who died between 17 to 34 years were included in this study than adults died between their 35 and 50 years of age (middle adults) or after they reached 50 years (old adults). As the age at death distribution already suggests, significantly more young adults were present than middle and old adults (χ^2 = 30.3, df = 2, p = 0.001). Figure 8 illustrates the distribution of the three age at death groups, with the young adults being the most strongly represented, followed by middle and old adults.

When the middle and old adults were summed up as the age at death category of individuals who died over the age of 35 years old, no significant differences were noted between them and the younger adults (χ^2 = 728, df = 1, p = 0.082).

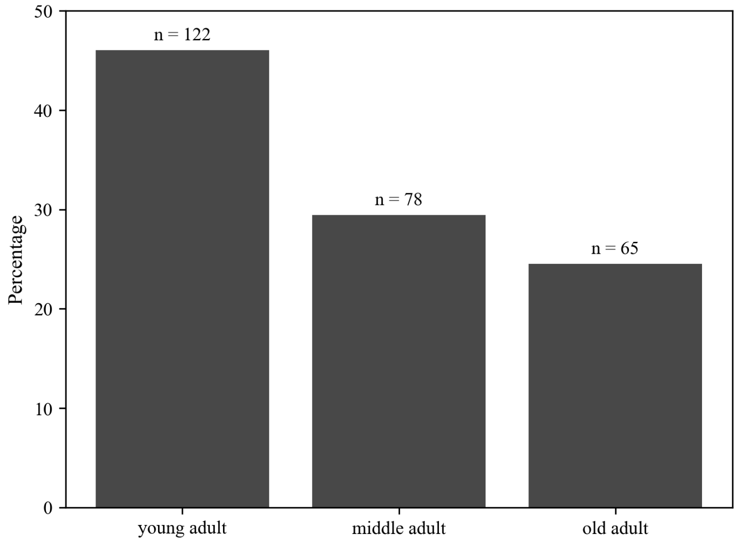

Figure 8: Distribution of age at death with individuals divided into young, middle and old adult

Table 7 presents the distribution of the individuals grouped by sex and age at death. Significant differences were noted in the male-to-female distribution between the age at death groups, with the middle adults being the most disparate between the sexes (χ^2 = 12.5, df = 2, p = 0.002). It is evident that the young male adults (n = 58) and middle male adults (n = 55) were almost evenly distributed compared to the old male adults, with only 29 individuals. Of the females, the young female adults were the most represented with 63 individuals, in contrast to the 22 middle female adults and the 33 old female adults. The indifferent individuals represented only one young adult, one middle adult, and three old adults.

Table 7: Sex and age at death distribution of all individuals

	male	female	indifferent
young adult	58 (40.8%)	63 (53.4%)	1 (20%)
middle adult	55 (38.7%)	22 (18.6%)	1 (20%)
old adult	29 (20.4%)	33 (28.0%)	3 (60%)
total	142 (100%)	118 (100%)	5 (100%)

The cemetery of Mödling - An der Goldenen Stiege was used from the first stage of the Middle Avar period to the last stage of the Late Avar period. The distribution of the Avar periods is shown in Table 8. The distribution between individuals buried in the Avar period reached a highly significant difference (χ^2 = 60.0, df = 2, p < 0.001), with most of the individuals (n = 124) being buried during the Middle Avar period (MA) according to their position in the cemetery and their grave goods. Less individuals were buried over time with 99 individuals during the Late Avar period

(SPA) and 42 during the Late Avar I period (SPA I). The results presented a decline in buried individuals over time.

Table 8: Distribution of individuals buried in the cemetery during the Avar periods

Period	n	%
MA	124	46.8%
SPA	99	37.4%
SPA I	42	15.8%
total	265	100%

7.3 Fractures and trauma

In total, there were 19 cases of fractures and 11 cases of trauma, which resulted in a total of 30 cases of injuries. Table 9 shows that 18 individuals (6.8%) were injured, which meant they had either a fracture, a trauma, or both. Of the 18 injured individuals, ten had only fractures, six had only traumas, and two individuals had both fractures and traumas. Significantly fewer individuals had injuries than individuals who were not injured in Mödling ($\chi^2 < 0.01$, df $= 1$, p < 0.001).

Table 9: Injured individuals

	N	%
injured	18	6.8
not injured	247	93.2

Figure 9 presents the burial ground of Mödling - An der Goldenen Stiege with over 500 individuals. The graves marked in red were associated with individuals who sustained an injury and were recorded in this thesis.

Table 10 lists all individuals with their serial number, grave ID, sex, age at death, type of injury, complications, and the associated Avar period. In three cases, it was impossible to determine the type of fracture because the bone had remodelled to such an extent that the fracture line could no longer be seen or there was too much postmortem damage. Every injury in this sample had occurred antemortem and presented signs of healing. Perimortem and postmortem injuries were looked for, but not found.

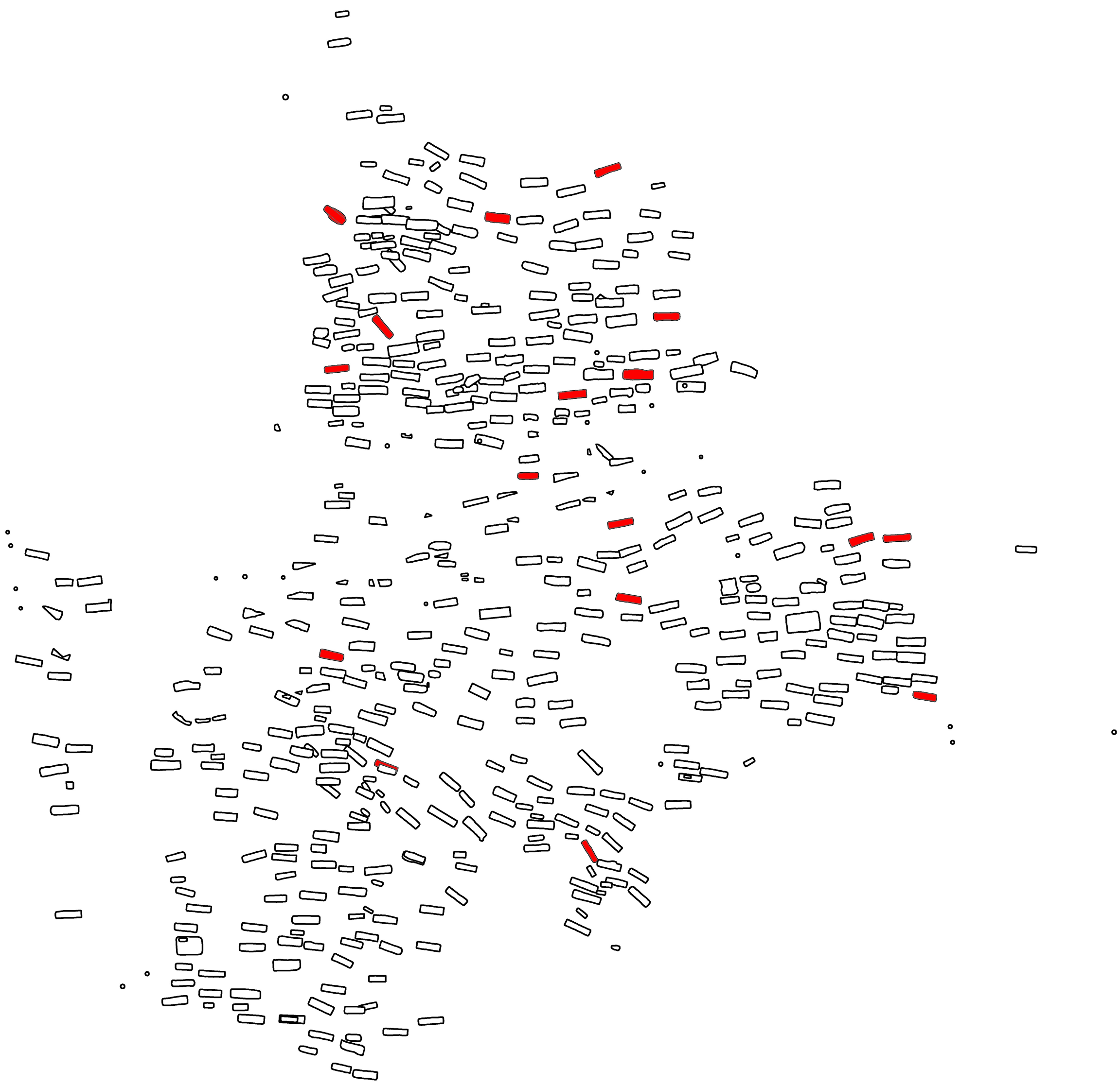

Figure 9: The burials of the cemetery of Mödling - An der Goldenen Stiege. The red squares represent the injured individuals recorded in this thesis (adapted from Bendeguz Tobias)

Table 10: All injured individuals listed with their serial number, grave ID, sex, age at death, type of fracture or trauma, complication and associated Avar period

Nr.	ID	sex	age at death	fracture/trauma	complication	Avar period
1	29	m	middle adult	oblique clavicle fracture		MA
2	50	m	middle adult	oblique femur fracture	shortened, deformed	MA
3	89	m	middle adult	oblique clavicle fracture	deformed	MA
4	94	m	middle adult	comminuted humerus fracture	inflammation, deformed	MA
5	112	m	old adult	oblique ulna fracture		SPA I
6	139	m	middle adult	oblique tibia fracture	bony fusion, shifted	SPA I
				oblique fibula fracture		
7	213	f	middle adult	stress reaction on femur	inflammation	MA
8	216	m	middle adult	soft-tissue injury on tibia		MA
				soft-tissue injury on fibula		
9	229	f	young adult	soft-tissue injury on tibia	inflammation	SPA
				soft-tissue injury on fibula	inflammation	
10	238	m	young adult	oblique ulna fracture		MA
				oblique ulna fracture		
				spiral/oblique tibia fracture	shifted, shortened, deformed	
				oblique fibula fracture	shifted, bone formation	
11	258	f	middle adult	oblique fibula fracture		SPA
12	261	m	middle adult	soft-tissue injury on tibia		MA
				soft-tissue injury on fibula		
13	312	m	old adult	soft-tissue cut on femur	inflammation	MA
14	334	m	young adult	soft-tissue injury on radius		MA
15	343	m	old adult	impacted humerus fracture	bone formation	SPA
				soft-tissue trauma on humerus	bone formation	
				oblique fibula fracture	shifted, inflammation	
16	379	m	middle adult	tibia fracture	inflammation (cloace?)	SPA
				fibula fracture	inflammation	
17	403	f	young adult	transverse ulna fracture		MA
18	425	m	middle adult	soft-tissue injury on tibia	new bone formation	SPA I
				comminuted fibula fracture	deformed	
				comminuted fibula fracture	deformed	

7.3.1 Detailed description of the individuals showing injuries

In the following chapter, all recorded fractures and traumas are discussed in terms of description of injury, type of mechanism of injury, type of fracture or trauma, complications, and descriptions of associated bones, if any. In the appendix, the description of four individuals with uncertain cases and a possible fibula amputation are discussed.

Individual 1: InvNr 27712, Grave ID 29: a male died as middle adult

A healed oblique fracture on the left clavicula had occurred in this male died as middle adult caused by indirect trauma. The fracture was closed and extraarticular. The AO classification would define the fracture as A2 (Kuner and Schlosser, 1995). The fracture has healed well and must have had a long time to heal. The axis of the shaft was shifted. The clavicula was internally rotated and presented an angulation of 5° (± 2°). The ventral side was influenced by muscle traction and lead therefore to a secondary overextension. It was evident that after the fracture occurred, the clavicula was still in use as the muscle attachments seemed pronounced. It was impossible to determine the potential shortening of the bone as the claviculas were damaged postmortem. There was no associated scapula to assess any deformation or consequences of the healed fracture, such as osteoarthritis. The associated left humerus was not entirely preserved as well; however, the muscle attachment for *M. pectoralis major* was very pronounced. No other injuries were observed in the skeletal remains of this individual.

Figure 10: Nr.1, InvNr 27712, Grave 29: healed oblique fracture of the left clavicula. The red square presents the affected healed area with signs of a shifted axis (photographed by A.Wagner)

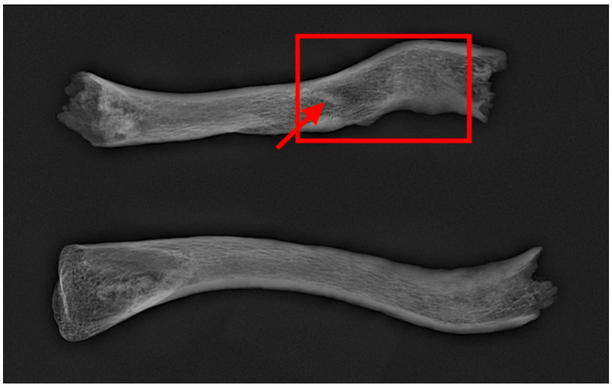

Figure 11: Nr.1, InvNr 27712, Grave 29: healed oblique fracture of the left clavicula. The red square presents the affected healed area with the fracture line visible (photographed by A.Wagner)

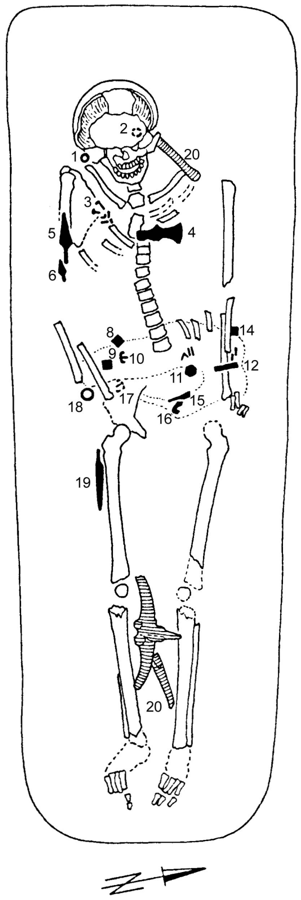

Figure 12: Nr.1, InvNr 27712, Grave 29: grave drawing of grave 29

Individual 2: InvNr 27736, Grave ID 50: a male died as middle adult

The right femur presented a healed oblique fracture between the proximal end and the middle of the shaft. The fracture was closed and extraarticular. According to the AO classification, it would be defined as A2 (Kuner and Schlosser, 1995). The oblique fracture line was visible on the x-ray image as seen in (Figure 14). The affected area was distinctly thickened, laterally shifted, and the bone had an angulation of 12°. The compact bone was newly remodelled and denser. The bone was measured from the end of the *trochanter minor* to the *linea intercondylaris*s and presented a shortening in comparison to the unaffected bone (R = 23.3 cm; L = 25.2 cm). The fracture may have been caused by a combined action of bending, torsion, and compression. In the case of a proximal fracture, the central fragment of the bone would have been pulled into a flexed position. As the bone is very well healed and no signs of inflammation are visible, treatment could have been possible such as non-operative treatment, such as immobilisation. A possible deformity depends on the severity of the fracture, the action of the associated muscular attachments, and the degree of soft-tissue stripping (Murray et al., 2008). The attached muscle with possible complications would have been the *M. vastus intermedius*, which spreads around the anterior side of the femur. An oblique fracture often involves bending wedges, and the most pain-relieving treatment would probably have been immobilisation (Kuner and Schlosser, 1995).

On the grave drawing (Figure 15) the healed fracture with the thickened callus is visible. No other injuries were observed in the skeletal remains of this individual.

Figure 13: Nr.2, InvNr 27736, Grave ID 50: overview of the right femur with a healed fractures (photographed by A.Wagner)

Figure 14: Nr.2, InvNr 27736, Grave ID 50: healed oblique fracture of the right femur. The red squares presents the affected area with a deformity and shifted axis (photographed by A.Wagner)

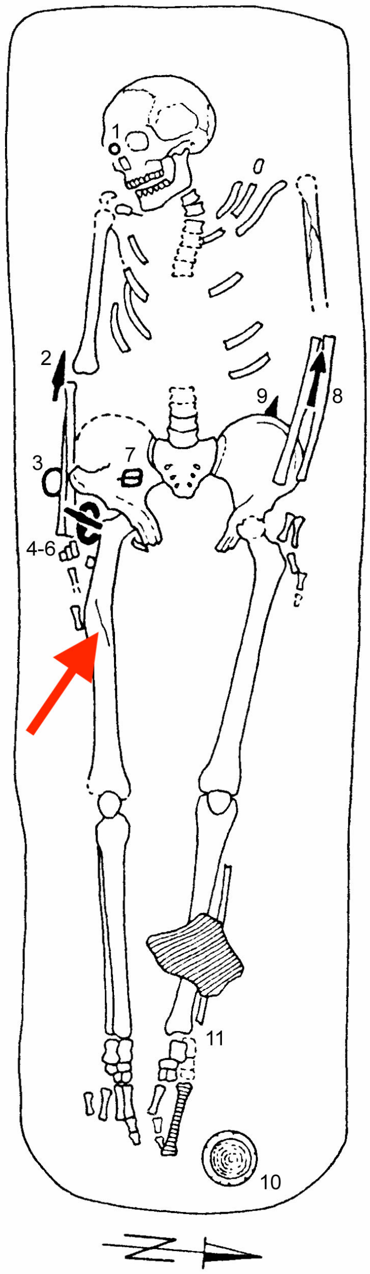

Figure 15: Nr.2, InvNr 27736, Grave ID 50: grave drawing of grave 50 with the right fractured femur visible

Individual 3: InvNr 27772, Grave ID 89: a male died as middle adult

A healed oblique fracture on the right clavicula was found, which may have been caused by an indirect trauma. The fracture was closed and extraarticular. The fracture healed well with much new bone formation and compaction of the bone. The axis of the shaft was twisted with an angulation of 8° (± 2°). The bone was deformed and possibly shortened. A measurement was impossible as both bones were not preserved well enough. The lateral end (*extremitas acromialis*) was vertically twisted. A complication following the fracture, could have been an inflammation. The associated right scapula presented marginal osteophytes and pitting of the glenoid fossa, which could indicate osteoarthritis as the source. Both humeri were not enough preserved to assess any deformation due to the fracture. No other injuries were observed in the skeletal remains of this individual.

Figure 16: Nr.3, InvNr 27772; Grave ID 89: healed oblique fracture of right clavicula. The red square presents the affected fractured area with signs of deformity. The red arrow points to a hole that had formed during the healing process (photographed by A.Wagner)

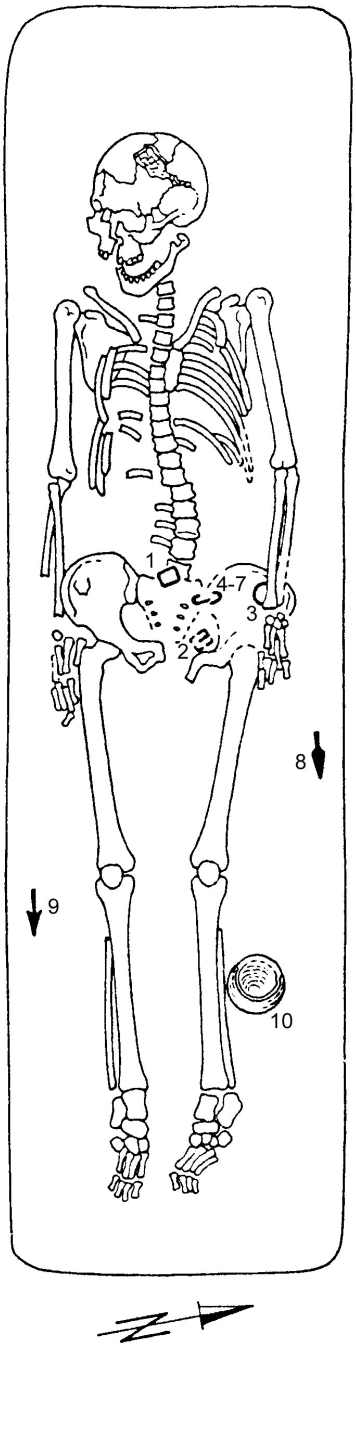

Figure 17: Nr.3, InvNr 27772; Grave ID 89: grave drawing of grave 89

Individual 4: InvNr 27776, Grave ID 94: a male died as middle adult

A healed comminuted fracture on the distal end of the left humerus was found. The fracture may have been open and extraarticular. There were no longer any fracture lines visible on the x-ray image, as the bone had healed very well. According to the AO classification, this fracture would have been characterised as C 3.3 with displacement and could have been accompanied by closed soft-tissue damage (Kuner and Schlosser, 1995). It was not characterised as a supracondylar fracture as the middle and distal end of the shaft were affected. However, the area of the supracondylar crest was involved. The affected area was completely remodelled and appeared to be denser in comparison to the right humerus. A complication of this fracture could have been infection with the possibility of osteomyelitis. The infection had been vast but had healed very well. The affected left humerus was deformed and showed a 5° angulation (± 2°). A shortening of the bone was impossible to be determined. The elbow joint involved did not seem to be strongly affected as the *trochlea humeri* did not show any signs of deformity. However, the *tuberositas ulnae* was strongly pronounced, which pointed to the usage of the arm after the fracture had occurred. Indirect or direct trauma can cause humerus shaft fractures; however, comminuted or multifragmented shaft fractures often resulted from trauma involving high-velocity forces (Kuner and Schlosser, 1995). No other injuries were observed in the skeletal remains of this individual.

Figure 18: Nr.4, InvNr 27776, Grave 94: healed comminuted fracture of the left humerus. The red square presents the fractured area with deformity. On the x-ray no fracture line is visible (photographed by A.Wagner)

Figure 19: Nr.4, InvNr 27776, Grave 94: healed fracture of the left humerus. The red arrow shows the possible cloaca caused by infection. The affected area is clearly deformed (photographed by A.Wagner)

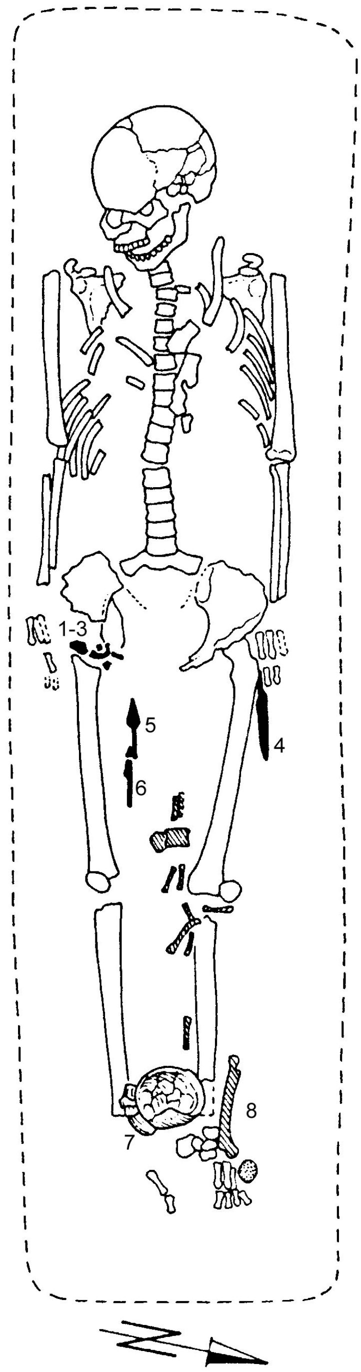

Figure 20: Nr.4, InvNr 27776, Grave 94: grave drawing of grave 94 with the left humerus visible

Individual 5: InvNr 27792, Grave ID 112: a male died as old adult

The right ulna presented a healed oblique fracture on the distal end of the shaft. The fracture was extraarticular and closed caused by indirect trauma. According to the AO classification, it would be type A1, a simple fracture, and the radius remained intact (Kuner and Schlosser, 1995). A potential deformity and shortening of the bone were impossible to determine as both ulnas were not entirely preserved. The angulation was measured to around 8° (± 2°). The associated radius did not show any signs of fracture lines or trauma; however, only part of the whole shaft was completely available. No other injuries were observed in the skeletal remains of this individual.

Figure 21: Nr.5, InvNr 27792, Grave ID 112: healed oblique fracture of the right ulna. The red square presents the affected fractured area (photographed by A.Wagner)

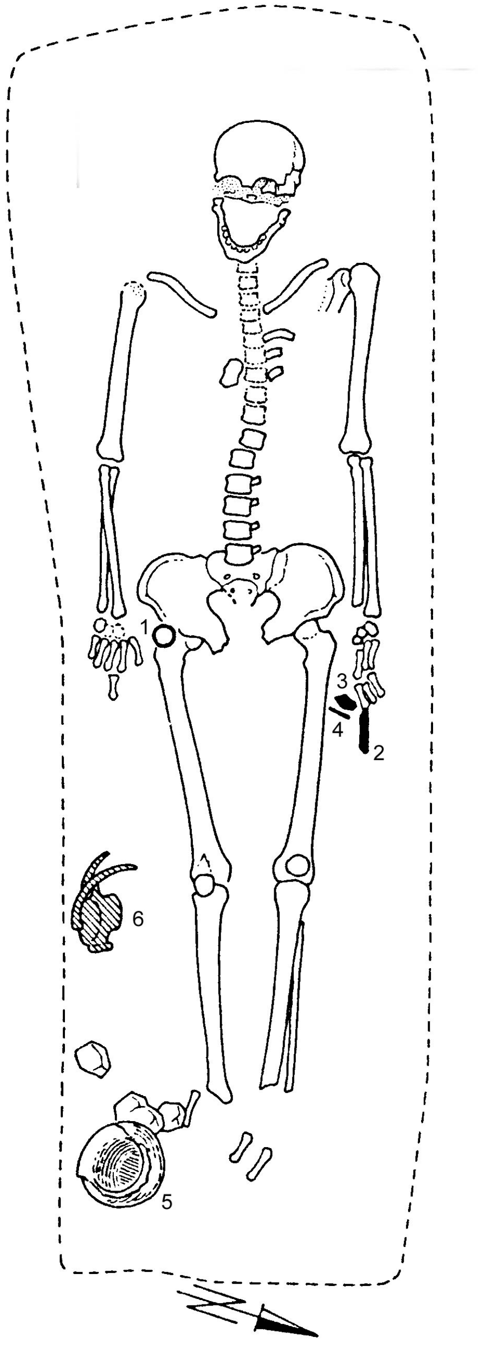

Figure 22: Nr.5, InvNr 27792, Grave ID 112: grave drawing of grave 112 with the ulnas visible

Individual 6: InvNr 27814, Grave ID 139: a male died as middle adult

The left tibia and fibula both presented healed oblique fractures on the distal end of the shaft resulting from indirect forces. The fractures were closed and extraarticular. According to the AO classification, these fractures would be defined as type A2 (Kuner and Schlosser, 1995). A bony fusion of the distal tibia and fibula following a fracture was present, but only a small part of the fused fibula was preserved. The compact bone was completely remodelled, shifted, and showing a denser bony structure. The axis of the bone was shifted medially and the angulation was 17° (± 2°). The affected area was rotated externally. The associated medial malleolus was broken off postmortem, but it was possible to reattach it to see the continuing axis of the bone. The malunion was very clear, but potential shortening of the tibia was impossible to determine as both the tibias and fibulas were not completely preserved. The associated foot with the calcaneus did not show any variation or changes due to the fractures, but very little was preserved. The associated left talus presented a rim built of marginal osteophytes on the subtalar articular surface. Indirect forces such as rotation or compression can result in spiral or oblique fractures, similar to that one observed here (Murray et al., 2008). The mechanism of the injury could have been an angular force as this would lead to a transverse or oblique fracture of the shaft. Proximal fibula shaft fractures commonly accompany distal tibial shaft fractures above the medial malleolus, which did not happen here. Concerning injury complications, in closed tibia fractures soft-tissue damage can be expected. A full union of the tibia shaft after a fracture can take four to 6 months. Malunion is likely to occur because of the difficulty of immobilising the leg and minimising weight-bearing (Lovell and Grauer, 2018; Lovell, 1997). Fractures of the tibia shaft with accompanying fibula shaft fractures, may have been difficult to manage because of their inherent instability (Dombroski et al., 2012). Other postcranial injuries included a well-healed fracture of the right fifth metacarpal bone in malalignment.

Figure 23: Nr.6, InvNr 27814, Grave ID 139: close up of the left tibia and fibula. The red square presents the fractured and fused area. The red arrows show the fracture lines (photographed by A.Wagner)

Figure 24: Nr.6, InvNr 27814, Grave ID 139: overview of the left tibia and fibula. The x-ray presents the broken off medial malleolus and illustrates the deformity and shifted axis (photographed by A.Wagner)

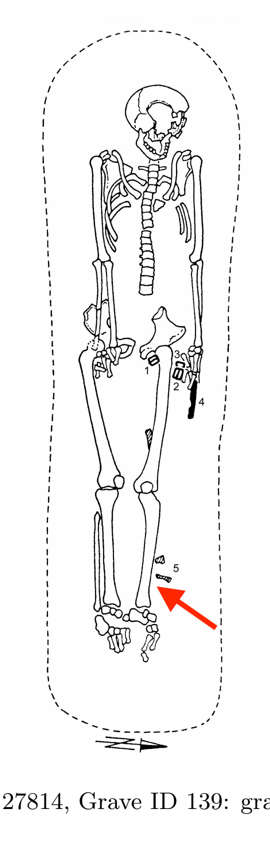

Figure 25: Nr.6, InvNr 27814, Grave ID 139: grave drawing of grave 139

Individual 7: InvNr 27886, Grave ID 213: a female died as middle adult

Around the muscle attachment from *M. vastus intermedius* was a bone formation visible in the middle of the right femur shaft. The new bone formation was placed on top of the compact bone, but the bone was denser around the affected area. The *linea aspera* seemed slightly squashed and built a rim of new bone formation around the affected area. One possible conclusion would be a periosteal reaction in addition to the callus formation because of a traumatic event, such as trying to carry too much weight. A complication could have been exostosis. A stress fracture was considered; however, it was impossible to determine from the x-ray image if this had really been the case. As stress fractures are the result of multiple traumatic events, this injury was diagnosed as a trauma. No other injuries were observed in the skeletal remains of this individual.

Figure 26: Nr.7, InvNr 27885, Grave 213: soft-tissue injury on the right femur. The red square presents the affected area with a squashed area and newly built rim (photographed by A.Wagner)

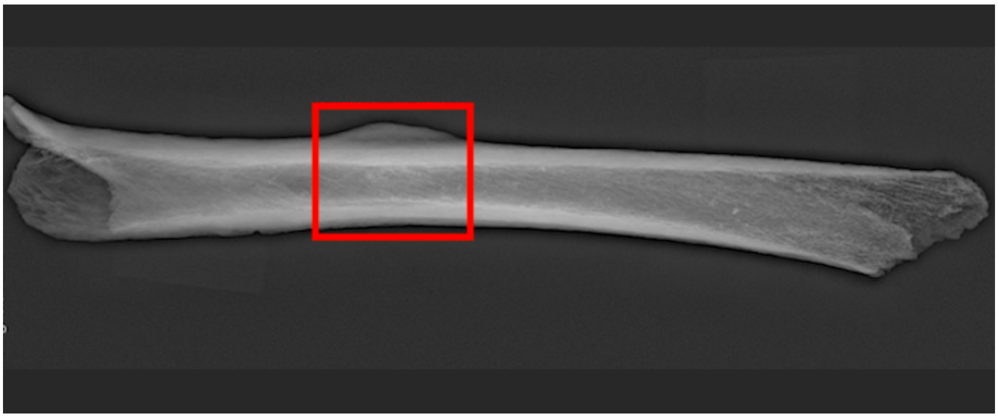

Figure 27: Nr.7, InvNr 27885, Grave 213: x-ray of the right femur with the affected area presented by a red squared. The compact bone was not affected (photographed by A.Wagner)

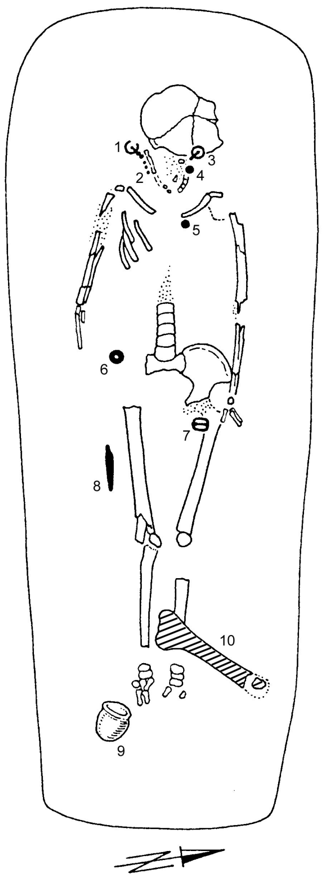

Figure 28: Nr.7, InvNr 27885, Grave 213: grave drawing of grave 213

Individual 8: InvNr 27888, Grave ID 216: a male died as middle adult

The right tibia presented a new bone formation on the proximal end in the form of a tip on the lateral condyle, where the fibula head attaches. It seemed that a trauma in the form of a soft-tissue injury occurred around the *facies articularis capitis fibulae* together with the proximal end of the fibula, but the bone structure inside of both was not affected. The *ligamentum capitis fibulae posterius* was probably involved as well. The associated fibula head seemed thickened around the affected area; though, both fibula heads were not completely preserved and damaged postmortem. It looked like the trauma led to a remodelling of the affected area, but nothing was visible on the x-ray image. The right tibia was possibly slightly shorter (R = 37.4 cm, L = 37.7 cm), but the natural asymmetry of the bones may be responsible. Shortening of the fibula was impossible to be determined as the associated fibula could not be measured. No other injuries were observed in the skeletal remains of this individual.

Figure 29: Nr.8, InvNr 27888, Grave 216: overview of the right tibia and fibula. The red squares present the affected areas. The compact bone was not affected as seen on the x-ray image (photographed by A.Wagner)

Figure 30: Nr.8, InvNr 27888, Grave 216: soft-tissue injury of the right tibia and fibula. The red squares present the affected areas. The red arrow shows the remodelled area of the fibula and the extent of the inflammation (photographed by A.Wagner)

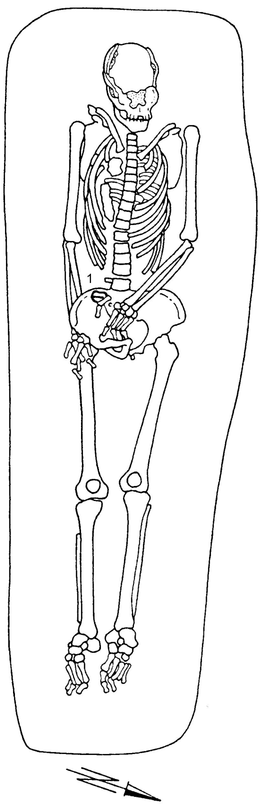

Figure 31: Nr.8, InvNr 27888, Grave 216: grave drawing of grave 216

Individual 9: InvNr 27894, Grave ID 229: a female died as young adult

The middle of the shaft of the right tibia shaft presented a periosteal reaction on top of the bone. The associated right fibula presented a periosteal reaction on the distal end of the shaft as well. The compact bone was partly remodelled on the medial side. There seemed to have occurred a trauma in form of a soft-tissue injury on both bones. The inflammation affected the distal end of the fibula and spread to the middle of the shaft and was still present at the time of death. The affected bone was flatter in comparison to the other fibula. The right femur presented a pronounced muscle attachment for the *M. gluteus maximus*, and the affected area also seemed to be inflamed; however, the area was damaged postmortem. The associated talus and calcaneus were not preserved. Other postcranial injuries included a hole with rounded margins on the right lateral ilium that could have resulted from an arrowhead injury.

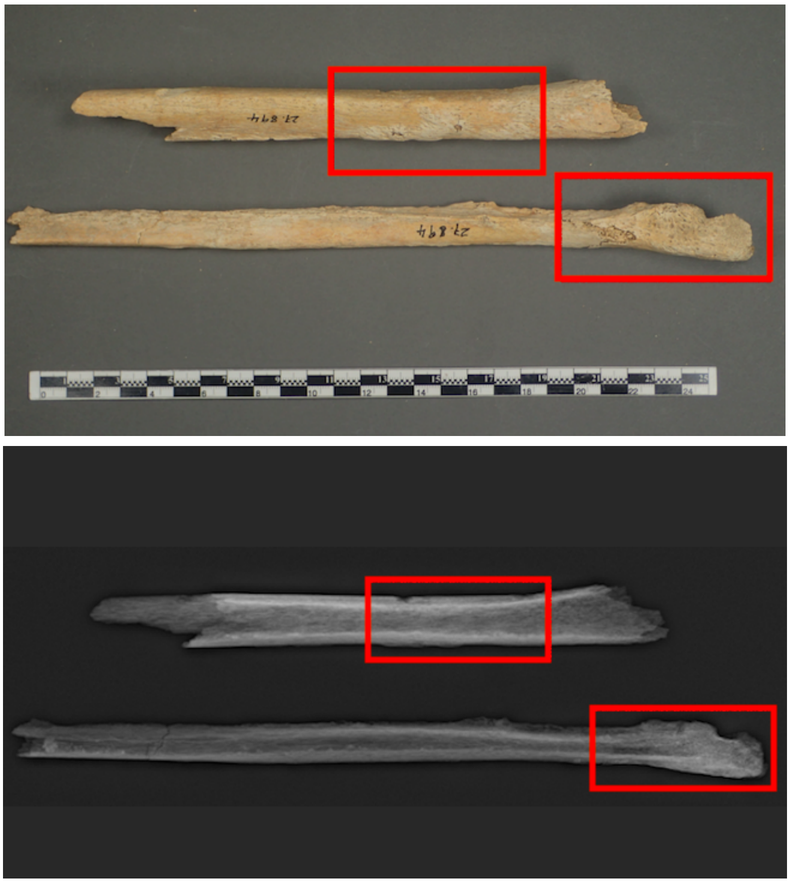

Figure 32: Nr.9, InvNr 27894, Grave 229: overview of the right tibia and fibula. The red squares present the affected inflammed areas (photographed by A.Wagner)

Figure 33: Nr.9, InvNr 27894, Grave 229: soft-tissue injury of the right fibula. The red square presents the highly remodelled and infected area. The red arrow points to the extent of the inflammation with new bone formation (photographed by A.Wagner)

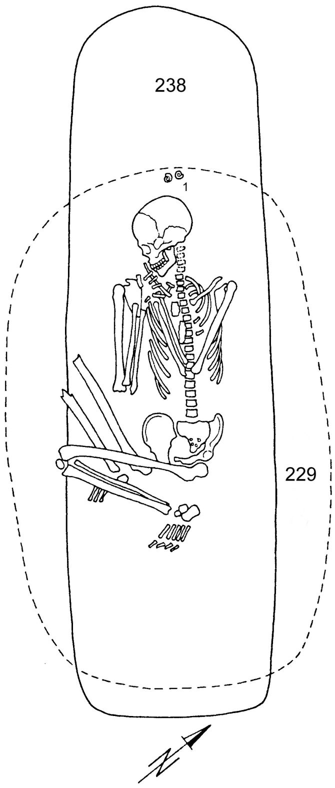

Figure 34: Nr.9, InvNr 27894, Grave 229: grave drawing of grave 229. The individual was buried on top of individual 238. The individual was buried in a squatting position

Individual 10: InvNr 27902, Grave ID 238: a male died as young adult

This individual presented four fractures with two healed fractures on the right and left ulna shafts as well as a fracture on the left tibia and fibula. All fractures were oblique resulting from an indirect trauma. The fractures were extraarticular and closed. The fracture on the right ulna had occurred more proximal on the shaft and was distinctly thicker than the affected area on the left ulna. The left ulna was visibly shorter than the right ulna (R = 24 cm, L = 23.3 cm). There seemed to be case of deformity and the styloid of both ulnas were very differently placed as well. According to the AO classification, the fractures would be type A1, which is defined as a simple fracture with an intact radius (Kuner and Schlosser, 1995). Both radii did not show any signs of fractures, trauma, deformity, or significant shortening (R = 21.9 cm, L = 21.7 cm). A possible complication could have been that the associated *membrana interossea antebrachia* may have been torn by the break while also stabilising the affected ulna.

Figure 35: Nr.10, InvNr 27902, Grave 238: The red squares present the fractured areas of the left and right ulnas (photographed by A.Wagner)

Figure 36: Nr.10, InvNr 27902 Grave ID 238: close-up of the oblique healed fractures of the left and right ulna. The red squares show that the fractures were not on the same level of the unlas (photographed by A.Wagner)

The left tibia and left fibula both presented healed fractures, which were closed and extraarticular. The fracture on the tibia occurred in the middle of the shaft spreading to the distal end and was either a closed spiral or oblique fracture, type A2. The original compact bone of the tibia was still visible, but the affected area was remodelled and thickened with callus build up. It was apparent that the axis of the tibia was shifted laterally, and the angulation measured to 7° (± 2°). The fracture on the associated left fibula occurred around the proximal part of the shaft spreading to the middle of the shaft. The bone was distinctly thickened and formed a hole in the new bone formation. The healed fracture was a closed oblique fracture, type A2 (Kuner and Schlosser, 1995). The fracture on the fibula resulted in a shift of the axis as well as a twisting of the bone with an angulation of 9°. Both tibias were not completely preserved but there was enough on both sides which allowed a measurement of the long bone. The affected left tibia was substantially shorter with 32.5 cm in comparison to the right tibia with 33.3 cm. A deformity and shortening of the bone were very apparent. The same was not possible for the fibulas as they were not preserved enough. Because both fractures seemed to be oblique and coming from the same side, it could be concluded that the force of impact, such as an indirect trauma, came from a diagonal lateral hit. Diaphyseal fractures of the lower extremity often involve both the tibia and fibula. Transverse or short oblique fractures of the shafts at roughly the same level often result from angular forces as the mechanism of injury (Lovell, 1997).

The injury sequence of all four fractures can no longer be determined. However, looking at the healing status, all injuries were completely healed. The fractures of the tibia and fibula were most likely caused by the same event. The ulna fractures also appear to be due to the same event. Since the individual was a young male adult, the conclusion of a single high-energy accident, probably a fall, seems reasonable.

Other postcranial injuries included a healed rib fracture with callus at the left rib 10 or 11.

Figure 37: Nr.10, InvNr 27902 Grave ID 238: healed fractures of the left tibia and fibula. The red square presents the fractured area with deformity on the tibia. The red arrow shows the new bone formation forming a hole around the fractured area on the fibula (photographed by A.Wagner)

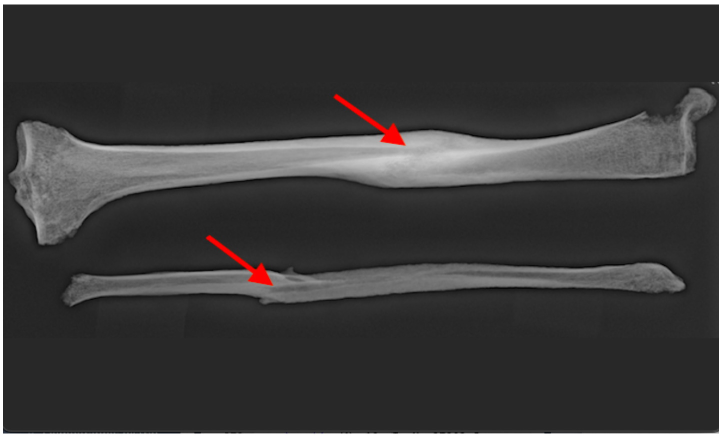

Figure 38: Nr.10, InvNr 27902 Grave ID 238: healed fractures of the left tibia and fibula. The red arrows present the visible fracture lines on the x-ray image (photographed by A.Wagner)

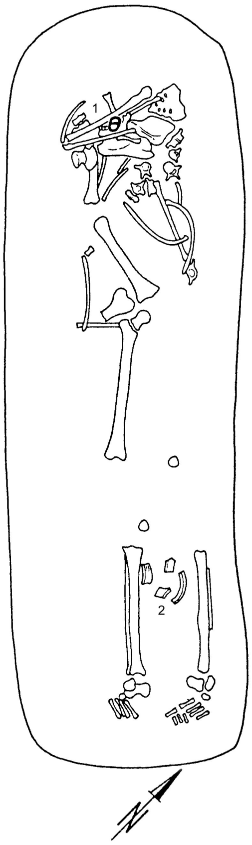

Figure 39: Nr.10, InvNr 27902 Grave ID 238: grave drawing of grave 238. The individual was disturbed, not in anatomical association except for the lower legs, and buried on top of individual 229

Individual 11: InvNr 27920, Grave ID 258: a female died as middle adult

The right fibula presented a thicker and flatter distal shaft resulting from a healed oblique fracture. The fracture was closed, extraarticular, and had healed very well until the time of death. The compact bone was dissolved, and the bone was newly remodelled. The asymmetry of the fibulas and the distinct thickening of the affected fibula spoke for the fact that a fracture had occurred. Other postcranial injuries included a potential greenstick fracture at the distal proximal phalanx of the fifth metacarpal and a potential greenstick fracture at the right proximal fourth metatarsal and a mildly collapsed 3rd metacarpal.

Figure 40: Nr.11, InvNr 27920, Grave 258: healed oblique fracture of the right fibula. The fractured flattened area is presented by the red square. The red arrow on the x-ray image shows the slightly visible fracture line (photographed by A.Wagner)

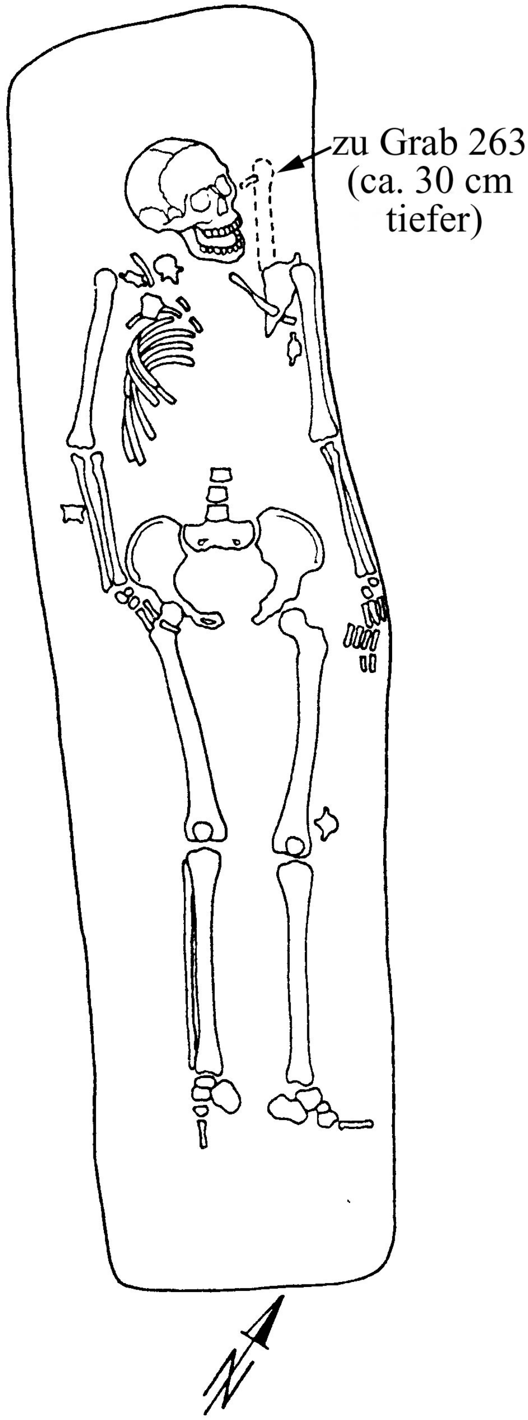

Figure 41: Nr.11, InvNr 27920, Grave 258: grave drawing of grave 258. The individual was buried on top of individual 263

Individual 12: InvNr 27922, Grave ID 261: a male died as middle adult

The right tibia presented a build up of new bone formations on the posterior side of the medial malleolus. The anterior side of the medial malleolus was thickened with uneven bone growth. The posterior side of the medial malleolus presented a dent, which started abruptly at the higher end of the new bone growth. An ankle sprain may have caused a rupture of the *flexor digitorum longus* and *tibialis posterior*, which resulted in the dent of the medial malleolus as well as an ossified muscle calcification (Kettelkamp and Alexander, 1969). The associated tendons (*flexor retinaculum*) of the medial malleolus could have been affected as well. These muscles should help keeping the pads of the toes on the ground while enlarging the weight-bearing area. *Tibialis posterior* controls the degree of pronation of the foot and the distribution of weight. The left fibula presented a similar new bone formation on the side of the lateral malleolus, which would have affected the *peroneus longus* as it runs distally behind the lateral malleolus. These muscles are important to maintain the concavity of the foot during toe-off and tiptoeing (Paulsen et al., 2022; Standring and Gray, 2021). The associated right talus presented a new bone formation in the form of a spike on the neck. The left calcaneus seemed to have larger joint surfaces on the dorsal side. The tibial tuberosities on both tibias were rather pronounced.

Other postcranial injuries included two hand fractures: a healed fifth metacarpal fracture at the right superior aspect with deformity and at the left 3rd metacarpal at the styloid process with a pseudounion.

Figure 42: Nr.12, InvNr 27922, Grave 261: soft-tissue injuries of the right tibia and fibula. The red arrows present the affected areas with new bone formations (photographed by A.Wagner)

Figure 43: Nr.12, InvNr 27922, Grave 261: soft-tissue injuries of the right tibia and fibula. The red square presents the affected area on the tibia. The red arrows present the affected area with new bone formations. The x-ray image shows that the compact bone was not affected (photographed by A.Wagner)

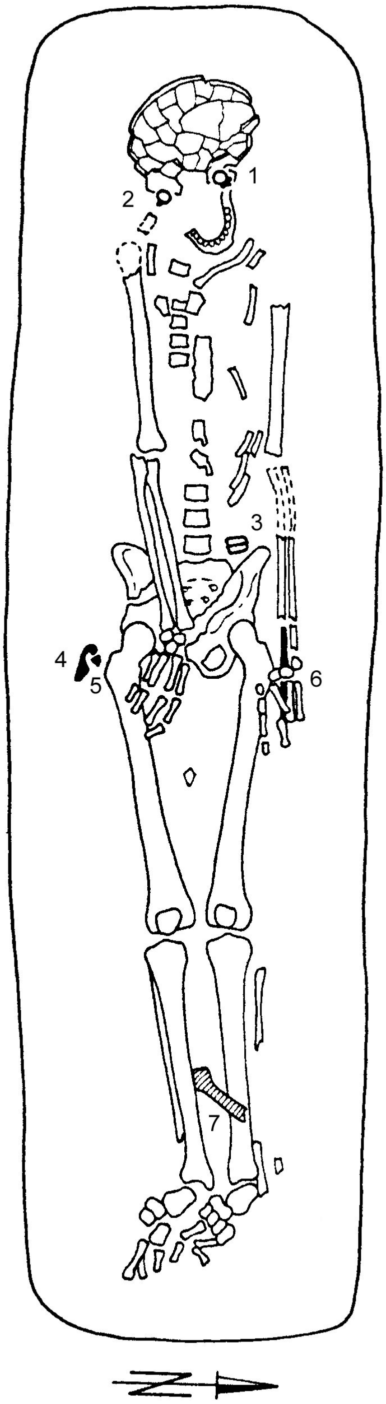

Figure 44: Nr.12, InvNr 27922, Grave 261: grave drawing of grave 261

Individual 13: InvNr 27974, Grave ID: 312: a male died as old adult

An impression in the form of a soft-tissue injury was visible on the left femur at the midshaft anterior surface. The injury was possibly caused by a direct trauma in the form of a direct blow with a sharp object. The affected area was 4.9 cm long and 1 cm wide. The compact bone did not seem to be affected, and the injury occurred on top of it. The area around the impression was little inflamed and presented a periosteal reaction by the time of death. The injury was in a healing process.

Other postcranial injuries included a hand fracture with a healed fracture of the fifth metacarpal on the right side.

Figure 45: Nr.13, InvNr 27974, Grave ID 312: soft-tissue trauma on the left femur. The red square presents the affected are. The red arrow shows the impression close-up with signs of inflammation (photographed by A.Wagner)

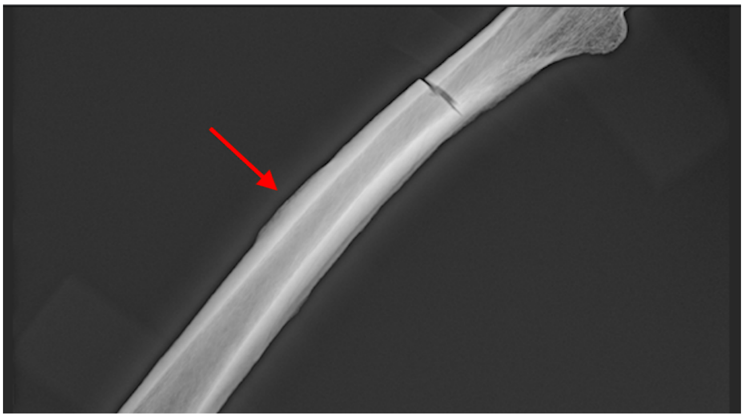

Figure 46: Nr.13, InvNr 27974, Grave ID 312: x-ray of the left femur. The red arrow shows the affected area and that the compact bone was not affected by the impression (photographed by A.Wagner)

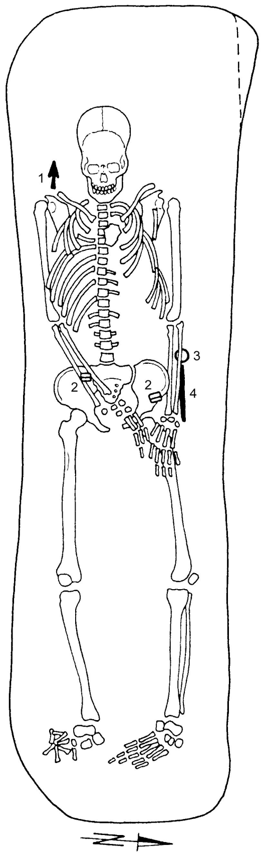

Figure 47: Nr.13, InvNr 27974, Grave ID 312: grave drawing of grave 312

Individual 14: InvNr 27997, Grave ID 334: a male died as young adult

Both radii showed extra bone growth on the *margo interosseus*, however, only the right side experienced a traumatic process. The x-ray image below shows that the interior of the bone was not affected. Therefore, the soft-tissue injury was probably caused by a tear on the proximal end of the *margo interosseus*. This kind of injury can occur when falling on the outstretched arm, which often results in a fracture of the radial head (Soubeyrand et al., 2006), but did not happen in this case.

Other postcranial injuries included a possible ossified tendon spur at the right base of the fourth metacarpal. The individual was decapitated and had cuts on C6 and C7. In the Figure 48, it can be seen that the left radius has a green colour, which was caused by bronze grave goods that laid on top of the bone.

Figure 48: Nr. 14, InvNr 27997, Grave ID 334: soft-tissue trauma on the right radius. The red arrow and square present the affected area with new bone formation (photographed by A.Wagner)

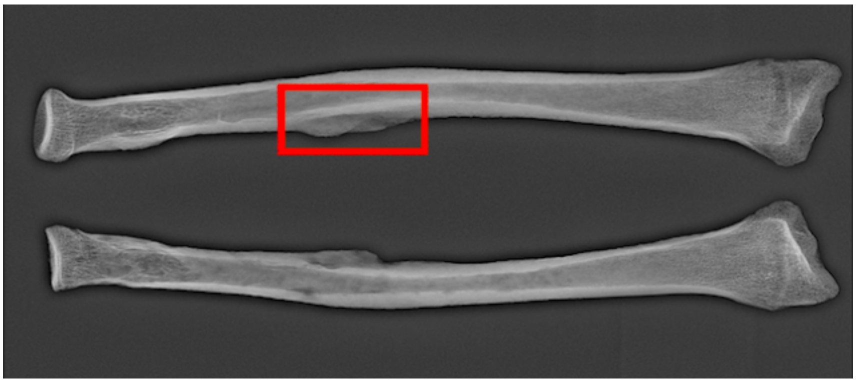

Figure 49: Nr. 14, InvNr 27997, Grave ID 334: x-ray of the soft-tissue trauma on the right radius (photographed by A.Wagner)

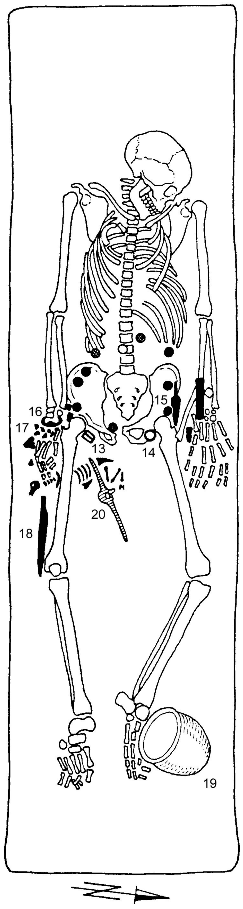

Figure 50: Nr. 14, InvNr 27997, Grave ID 334: grave drawing of grave 334

Individual 15: InvNr 28006, Grave ID 343: a male died as old adult

The right humerus showed signs of inflammation and new bone formation. A fracture line itself was not visible, but an impacted fracture probably occurred at the neck of the humerus caused by indirect trauma, such as a fall on an outstretched arm. The healed fracture may have been intraarticular and closed. A potential deformity or shortening of the bone was not possible to determine as the affected humerus was not entirely preserved. In addition to the healed fracture, a muscle tear from the *M. teres major* was present, which resulted in new bone formations around the proximal end of the shaft as well as signs of inflammation. This ossified bone formation was likely the result of *myositis ossificans traumatica*. The left fibula presented a healed oblique fracture in the middle of the shaft, where the fracture line was clearly visible on the x-ray image below. The fracture was closed and extraarticular. The affected area presented distinct thickening, callus, and a small hole. Around the new bone formation were signs of inflammation and periosteal reaction. The bone was deformed as the axis of the shaft was shifted laterally and angulation measured to 3° (± 2°). Potential shortening of the bone was impossible to determine. The fracture had healed very well. Other postcranial injuries include a healed fracture of the distal 3rd metacarpal on the right side as well as well-healed rib fractures on two probable right midribs.

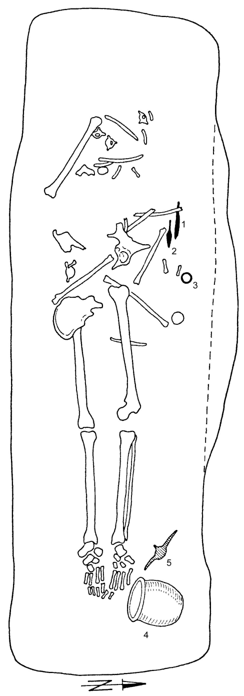

Figure 51: Nr.15, InvNr 28006, Grave ID 343: grave drawing of grave 343. The grave was disturbed but the lower legs remained in anatomical position

Figure 52: Nr.15, InvNr 28006, Grave ID 343: fractured humerus with soft-tissue injury. The red arrows show the muscle tear and new bone formation due to the fracture. The axis of the fibula shifted due to the fracture represented by the red arrow (photographed by A.Wagner)

Individual 16: InvNr 28040, Grave ID 379: a male died as middle adult

An inflammation affected the medial malleolus of the left tibia and the lateral malleolus of the fibula and spread to the distal end of the shaft. In both cases, the compact bone was not affected, and the new bone formations were placed on the top. Fractures occurred at the medial malleolus and lateral malleolus, but there were no fracture lines visible anymore as the bone was completely remodelled. Since there seemed to be a sign of a cloacae at the malleolus medialis, the trauma may have resulted in an osteomyelitis and presented signs of periostitis as well. The associated left talus was not well preserved but did not show any signs of inflammation. The associated left calcaneus did not show signs of inflammation as well but the joint surface of both calcanei on the dorsal side was rather flat. Extensive complications could have occurred, such as movement restrictions and pain. No other injuries were observed in the skeletal remains of this individual.

Figure 53: Nr.16, InvNr 28040, Grave 379: soft-tissue injuries on the left tibia and fibula. The red arrows show the new bone formation and inflammation caused by the injury. The red squares on the x-ray image present the affected area (photographed by A.Wagner)

Figure 54: Nr.16, InvNr 28040, Grave 379: close-ups of the soft-tissue injuries on the left tibia and fibula. The red arrows show the possible cloace from inflammation and the extent of the inflammation (photographed by A.Wagner)

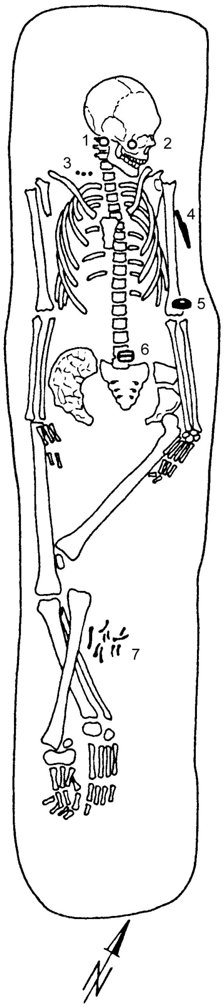

Figure 55: Nr.16, InvNr 28040, Grave ID 379: grave drawing of grave 379

Individual 17: InvNr 28068, Grave ID 403: a female died as young adult

The left ulna presented a transverse fracture caused by a direct trauma. The fracture was closed and extraarticular. The callus was clearly visible, and the area around the healed fracture was distinctly thickened. On the x-ray image, it was clear that the fracture had healed very well and had to have occurred a long time before death. The AO classification: type A1, which is defined as a simple fracture with an intact radius (Kuner and Schlosser, 1995). A possible complication with the associated radii was impossible to determine as the right radius was not preserved at all, and from the left radius, only parts of the shaft were available. The right ulna was slightly shorter than the affected left ulna (R = 23.4 cm L = 23.0 cm), which pointed to possible shortening of the bone. No other injuries were observed in the skeletal remains of this individual.

Figure 56: Nr.17, InvNr 28068, Grave ID 403: healed transverse ulna fracture. The red arrow and square show the affected area (photographed by A.Wagner)

Individual 18: InvNr: 28078 Grave ID: 425: a male died as middle adult

The right tibia showed a new bone formation on the proximal end in the form of at tip on the lateral condyle, where the head of the associated fibula attaches. The new bone formation seemed to have grown on top of the compact bone, which means the traumatic event, which led to the fractured fibula was accompanied by muscle irritation from the soleus muscle. The associated right fibula and the left fibula presented healed fractures on the fibula head. The closed and healed fractures were most likely comminuted fractures, but it was not possible to determine anymore as the bones were remodelled and no fracture lines were visible. The fibula heads seemed thickened through the callus formation, although the right fibula head seemed more remodelled in comparison to the left fibula head. On both sides, the compact bone was disintegrated and completely remodelled. Both fractures have had a long time to heal. Dirt and postmortem damage made the analysis more difficult. On both femora were signs of moderate osteoarthritis on the femoral head, and *fovea capitis* were visible and new bone formations on the *M. trochanter major*. Both femora had very pronounced muscle attachments and the skeletal remains seemed rather muscular in general.

Other postcranial injuries include a healed fracture of the left distal fifth metacarpal and a collapsed vertebra (cranial, probably L3).

Figure 57: Nr.18, InvNr 28078, Grave ID 425: overview of the fractured fibula heads and soft-tissue injury on the tibia. The red arrows point to the affected areas (photographed by A.Wagner)

Figure 58: Nr.18, InvNr 28078, Grave ID 425: close-ups of the fractured fibula heads. The red arrow points to the soft-tissue injury on the tibia (photographed by A.Wagner)

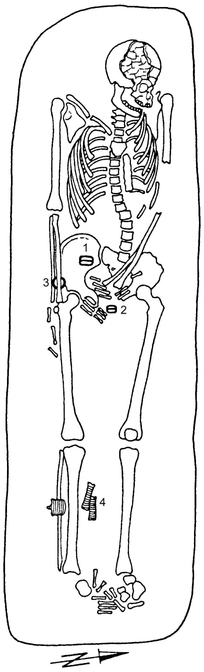

Figure 59: Nr.18, InvNr 28078, Grave ID 425: grave drawing of grave 425

7.3.2 Prevalence of injuries

In this study, 18 of 265 individuals (6.8%) exhibited either a fracture, a trauma, or both, which led to a total of 30 cases of injuries. In total, 2992 long bones were examined with 30 injuries (1%). There were 19 cases of fractures and 11 cases of traumas. All the fractures and traumas presented signs of healing and were therefore identified as antemortem injuries. No perimortem or postmortem injuries were recorded. Of the 19 fractures, 12 were oblique (with one possibly spiral), 3 comminuted, 1 transverse, and 2 were unidentifiable.

The distribution of injuries was analysed according to both sex and age at death. Of the 265 individuals, four females (1.5%) were injured with two females (0.8%) presenting one fracture each and two females (0.8%) presenting traumas. Of the two females with traumas, one had one trauma and one had two traumas. In this study, eight males (3.0%) showed only fractures, four males (1.5%) showed only traumas, and two males (0.8%) both exhibited two fractures and one trauma. This means, 14 males (5.3%) and 4 females (1.5%) out of 265 individuals exhibited injuries. The distribution of injuries among the sex was as follows: fractures 10 out of 14 males, 2 out of 4 females; traumas 6 out of 14 males, 2 out of 4 females. Both between injured and not injured males as well as injured and not injured females significant differences were noted ($\chi^2 = 0.03$, df = 1, $p < 0.001$), with the injured individuals being significantly fewer.

In total, eleven middle adults (4.2%), four young adults (1.5%), and three old adults (1.1%) exhibited injuries. The distribution of injuries among the three different age at death groups was as follows: fractures 2 out of 122 young adults, 8 out of 78 middle adults, 2 out of 65 old adults; traumas 2 out of 122 young adults, 4 out of 78 middle adults, 2 out of 65 old adults. One old adult exhibited both fractures and traumas, meaning this person was counted twice in this comparison. The not injured individuals were significantly fewer ($\chi^2 = 0.03$, df = 1, $p = 0.000$) in each group among all three age at death groups (young/middle/old). The middle adults (died between 35 and 49 years) presented the highest frequency of injuries. Analysis of the age range of injured middle adults showed that neither younger (around 35) nor older individuals (around 45) were in the majority within this age at death group.

Fractures and trauma were unevenly distributed among age at death and sex, as shown in Tables 11 and 12. Overall, there were more males with fractures (7.0%) than females (1.7%). In this sample, the middle adults exhibited the highest frequency of fractures (10.2%) compared to the young adults (1.6%) and old adults (3.1%). The same calculations were performed for trauma-related injuries. Table 12 presents the distribution of individuals with traumas per sex and age at death. The middle adults presented the highest number of trauma-injured individuals at four (5.1%). The same pattern in trauma as in fractures occurred in young adults (1.6%) and old adults (3.1%) with two affected individuals in each age at death group.

Table 11: The distribution of fracture frequencies calculated by individual for age at death and sex

	young adult n/N (%)	middle adult n/N (%)	old adult n/N (%)	total n/N (%)
male	1/58 (1.7%)	7/55 (12.7%)	2/29 (6.8%)	10/142 (7.0%)
female	1/63 (1.6%)	1/22 (4.5%)	0/33 (0.0%)	2/118 (1.7%)
indifferent	0/1 (0.0%)	0/1 (0.0%)	0/3 (0.0%)	0/5 (0.0%)
total	2/122 (1.6%)	8/78 (10.3%)	2/65 (3.1%)	12/265 (4.5%)

n = number of individuals exhibiting fractures; N = number of examined individuals in this age at death group; % = percentage of individuals exhibiting fractures in this group

Table 12: The distribution of trauma frequencies calculated by individual for age at death and sex

	young adult n/N (%)	middle adult n/N (%)	old adult n/N (%)	total n/N (%)
male	1/58 (1.7%)	3/55 (5.4%)	2/29 (6.8%)	6/142 (4.2%)
female	1/63 (1.6%)	1/22 (4.5%)	0/33 (0.0%)	2/118 (1.7%)
indifferent	0/1 (0.0%)	0/1 (0.0%)	0/3 (0.0%)	0/5 (0.0%)
total	2/122 (1.6%)	4/78 (5.1%)	2/65 (3.1%)	8/265 (3.0%)

n = number of individuals exhibiting trauma; N = number of examined individuals in this age at death group; % = percentage of individuals exhibiting trauma in this group

The following Figures (Figs. 60 and 61) illustrate the distribution of sex and age at death among affected individuals with fractures and traumas. With the exception of the male middle adults, the distribution of fractures and trauma was identical for the male and female young adults and the old male adults. None of the old female individuals sustained a fracture or trauma.

The frequency of fractures of the long bones (n = 19), separated by side, is shown in Table 13. In the left long bones, each segment had at least one fracture. The left distal end of the shaft (segment 4) showed the highest frequency of fractures (26.3%) with one humerus fracture (5.3%), two ulna fractures (10.5%), one tibia fracture (5.3%), and one fibula fracture (5.3%). The distal end of the right shaft (segment 4) exhibited the highest fracture frequency on the right side (15.8%) with two ulna fractures (10.5%) and one fibula fracture (5.3%). It was evident that the left side exhibited more fractures than the right side. Figure 62 presents the percentage of fractures that occurred, grouped by long bone. It was very clear that the fibula presented the highest frequency of fractures with 36.8% of all long bone fractures (7 out of 19). The ulna exhibited the second highest frequency of fractures with 21% (4 out of 19), followed by the tibia with 15.8% (3 out of 19). Both the clavicle and humerus exhibited identical numbers of fractures (n = 2 and 10.5% each). Finally, the femur accounted for only 5.3% of the fractures (1 out of 19), and the radius exhibited no fractures at all.

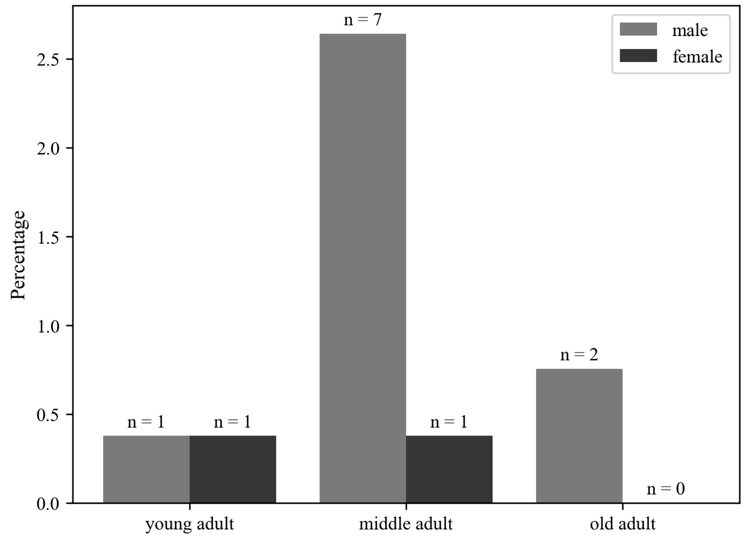

Figure 60: Distribution of fractures among the sexes and age at death groups. Only males and females are shown in this Figure, since no indifferent individual suffered a fracture

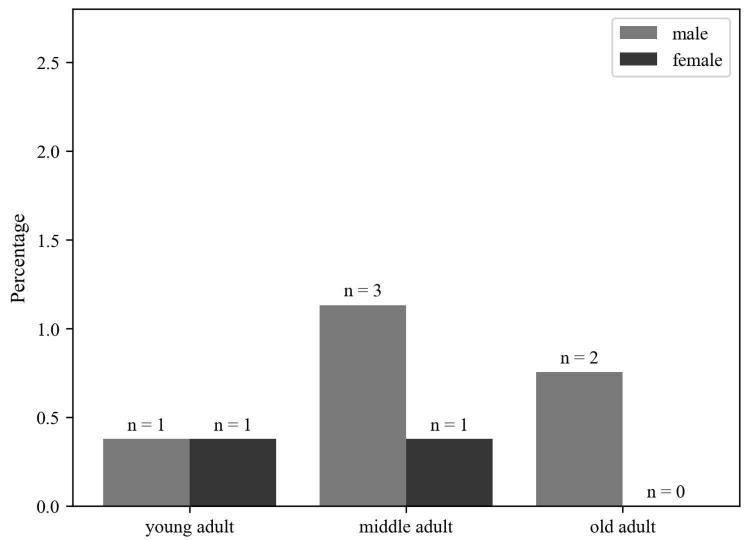

Figure 61: Distribution of traumas among the sexes and age at death. Only males and females are shown in this Figure, since no indifferent individual suffered a trauma

Table 13: Fracture pattern description of all long bones divided by side (left/right)

	L					R				
	1	2	3	4	5	1	2	3	4	5
Clavicula	0 -	1 (5.3%)	0 -	0 -	0 -	0 -	1 (5.3%)	0 -	0 -	0 -
Humerus	0 -	0 -	0 -	1 (5.3%)	0 -	1 (5.3%)	0 -	0 -	0 -	0 -
Radius	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Ulna	0 -	0 -	0 -	2 (10.5%)	0 -	0 -	0 -	0 -	2 (10.5%)	0 -
Femur	0 -	0 -	0 -	0 -	0 -	0 -	1 (5.3%)	0 -	0 -	0 -
Tibia	0 -	0 -	1 (5.3%)	1 (5.3%)	1 (5.3%)	0 -	0 -	0 -	0 -	0 -
Fibula	1 (5.3%)	0 -	2 (10.5%)	1 (5.3%)	1 (5.3%)	1 (5.3%)	0 -	0 -	1 (5.3%)	0 -
Total	1 (5.3%)	1 (5.3%)	2 (10.5%)	5 (26.3%)	3 (15.8%)	2 (10.5%)	2 (10.5%)	0 -	3 (15.8%)	0 -

Table 14: Trauma pattern description of all long bones divided by side (left/right)

	L					R				
	1	2	3	4	5	1	2	3	4	5
Clavicula	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Humerus	0 -	0 -	0 -	0 -	0 -	0 -	1 (9.1%)	0 -	0 -	0 -
Radius	0 -	0 -	0 -	0 -	0 -	0 -	0 -	1 (9.1%)	0 -	0 -
Ulna	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Femur	0 -	0 -	1 (9.1%)	0 -	0 -	0 -	0 -	1 (9.1%)	0 -	0 -
Tibia	0 -	0 -	0 -	0 -	0 -	2 (18.2%)	0 -	1 (9.1%)	0 -	1 (9.1%)
Fibula	0 -	0 -	0 -	0 -	1 (9.1%)	1 (9.1%)	0 -	0 -	0 -	1 (9.1%)
Total	0 -	0 -	1 (9.1%)	0 -	1 (9.1%)	3 (27.3%)	1 (9.1%)	3 (27.3%)	0 -	2 (18.2%)

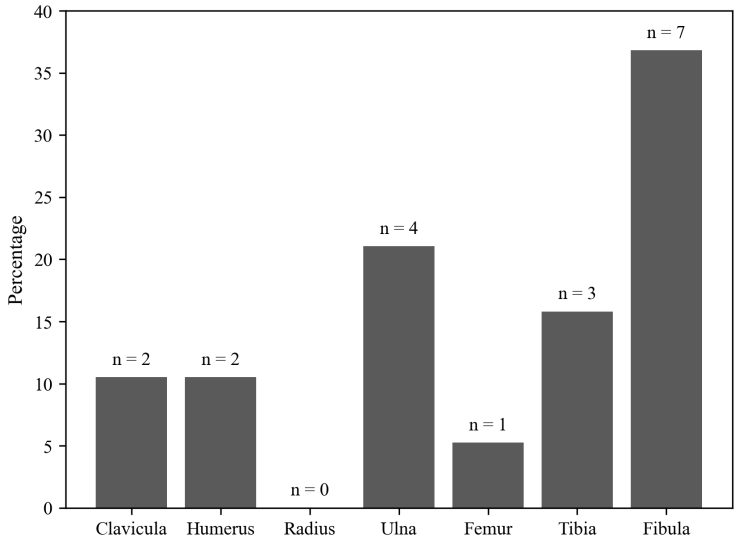

Figure 62: Distribution of fractures in long bones in males and females of all ages

A rather different pattern can be observed when analysing trauma-related injuries (n = 11; Table 14). The left side of the long bones presented only two traumas with one of them on the third segment of the femur (9.1%) and one on the fifth segment of the fibula (9.1%). On the right side of the long bones, the highest frequency of traumas occurred on the first segment with two tibia and one fibula trauma (27.3%) as well as the third segment with one radius, one femur and one tibia trauma (27.3%). In the case of trauma, more traumas were recorded on the right side (9 out of 11) than on the left (2 out of 11).

Figure 63 displays the traumas grouped by the affected long bone. In contrast to the fractures, here, the tibia exhibited the highest frequency of traumas with 36.4% (4 out of 11), followed by the fibula with 27.3% of all long bone traumas (3 out of 11). The region of the femur made up 18.2% of the traumas (2 out of 11). Both the humerus and radius presented the same amount of traumas (1 out of 11 each) with 9.1%. The clavicle and the ulna presented no traumas.

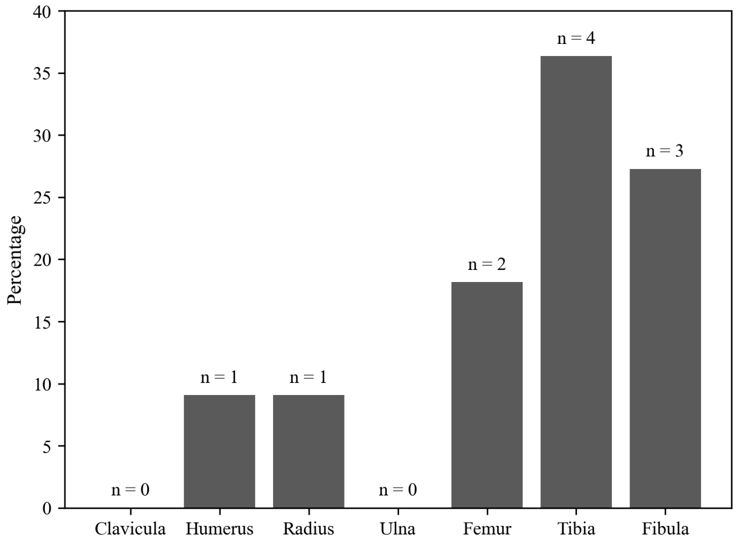

Figure 63: Distribution of trauma in long bones in males and females of all ages

Table 15 presents the fractures and traumas separately for the upper extremity (clavicle, humerus, radius, ulna) and the lower extremity (femur, tibia, fibula). More fractures occurred in the lower than in the upper extremity. A similar, but more pronounced, pattern was seen with trauma, as more trauma occurred to the lower extremity than to the upper extremity.

Table 15: Distribution of injuries by extremity of males and females and all ages

	fracture	trauma
upper extremity	8 (42.1%)	2 (18.2%)
lower extremity	11 (57.9%)	9 (81.8%)
total	19 (100.0%)	11 (100.0%)

The true prevalence rate (n long bone segments with injuries / N long bone segments in total) was calculated for each segment (1-5) for both sides of all long bones and is shown in Table 16. The majority of segments had no injuries. Each long bone had at least one injury. The most affected long bones were the fibula (10 injuries) and the tibia (7 injuries). Although the proximal end of the fibula (segment 1) was the least preserved on both sides, it had the highest true prevalence rate, 5.26% on the right fibula head and 2.9% on the left side. The distal ends of the fibula were also not well preserved compared with the shafts, but had 2.7% on the left fibula and 1.2% on the right fibula. The ulna had two injuries on segment 4 on both the left and right, resulting in a true prevalence of 1.2%, as the preservation of this segment was very similar.

Table 16: True prevalence rate of the fractures and traumas of all seven long bones calculated by side (left/right) and segment (1-5, clavicle had only 3 segments, which correspond to segments 1, 3 and 5, see Figure 5). In brackets are the number of injuries on this segment / amount of segments available

		Clavicula	Humerus	Radius	Ulna	Femur	Tibia	Fibula
L	1	0.0% (0/198)	0.0% (0/109)	0.0% (0/113)	0.0% (0/142)	0.0% (0/180)	0.0% (0/174)	2.9% (1/35)
	2	-	0.0% (0/220)	0.0% (0/188)	0.0% (0/184)	0.0% (0/249)	0.0% (0/243)	0.0% (0/137)
	3	0.5% (1/202)	0.0% (0/227)	0.0% (0/194)	0.0% (0/183)	0.4% (1/252)	0.4% (1/246)	1.3% (2/149)
	4	-	0.4% (1/224)	0.0% (0/185)	1.2% (2/161)	0.0% (0/251)	0.4% (1/242)	0.7% (1/148)
	5	0.0% (0/191)	0.0% (0/127)	0.0% (0/123)	0.0% (0/82)	0.0% (0/170)	0.5% (1/183)	2.7% (2/74)
R	1	0.0% (0/193)	0.9% (1/114)	0.0% (0/122)	0.0% (0/151)	0.0% (0/167)	1.2% (2/165)	5.6% (2/36)
	2	-	0.4% (1/226)	0.0% (0/195)	0.0% (0/192)	0.4% (1/241)	0.0% (0/239)	0.0% (0/156)
	3	0.5% (1/205)	0.0% (0/236)	0.5% (1/203)	0.0% (0/187)	0.4% (1/244)	0.4% (1/240)	0.0% (0/166)
	4	-	0.0% (0/236)	0.0% (0/199)	1.2% (2/165)	0.0% (0/244)	0.0% (0/237)	0.6% (1/160)
	5	0.0% (0/201)	0.0% (0/132)	0.0% (0/128)	0.0% (0/82)	0.0% (0/172)	0.5% (1/185)	1.2% (1/81)

The 18 affected individuals with their archaeological dating are shown in Table 17. Between the associated Avar periods, no significant differences were noted ($\chi^2 = 2.04$, df = 2, p = 0.360). It was evident that the most injured individuals belonged to MA with eleven persons (61.1%), followed by SPA with four individuals (22.2%) and SPA I with three individuals (16.7%). Thus, as more people were buried during the MA, there were also more injured individuals. The results indicate a pattern of decline over time for all persons buried in Mödling.

Table 17: Distribution of injuries by Avar period

Period	n/N	%
MA	11/124	8.9%
SPA	4/99	4.0%
SPA I	3/42	7.1%
total	18/265	6.8%

7.4 Test of hypotheses

Hypothesis 1: Testing the first hypothesis, which states that males have a higher injury prevalence altogether than females, revealed a significant difference (χ^2 = 3.11, df = 1, p = 0.0498): 14 males showed injuries compared to the 4 females. Figure 64 presents the distribution of the individuals without and with injuries divided by sex. Both in males and females, the majority were not injured. But more than three times as many males as females had injuries.

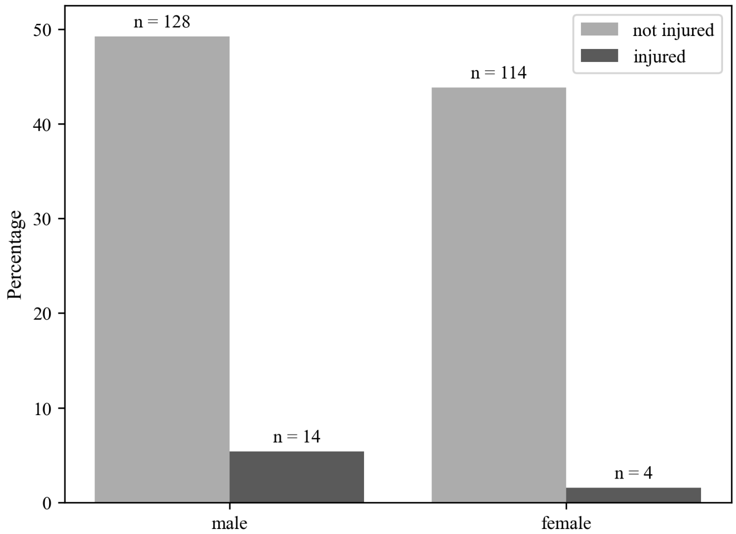

Figure 64: Distribution of long bone injuries in males and females

In summary, the first hypothesis, stating that males have a higher injury prevalence than females, was confirmed.

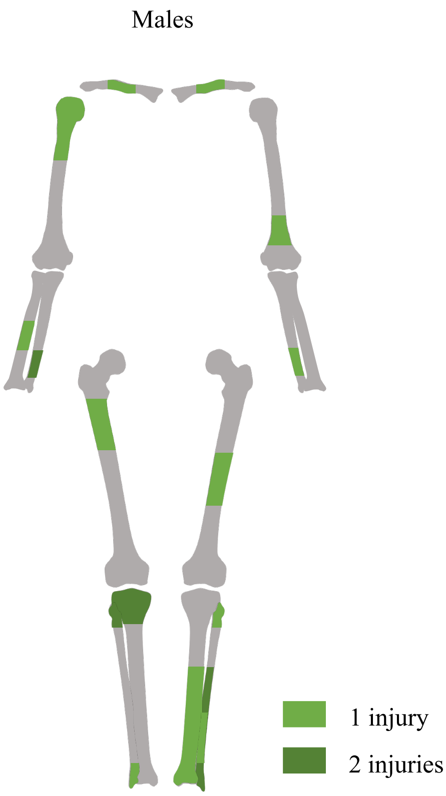

Figure 65: Summary of long bone injuries observed in males. Light green refers to one injury, dark green refers to two injuries (made by A.Wagner)

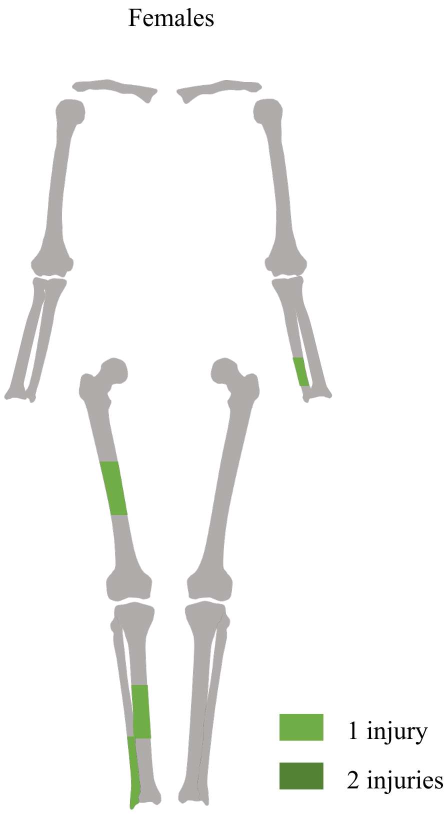

Figure 66: Summary of long bone injuries observed in females. Light green refers to one injury, dark green refers to two injuries (made by A.Wagner)

Hypothesis 2: The second hypothesis, which states that the prevalence of multiple injuries altogether is higher in males than females, did not reach statistical significance ($\chi^2 = 6.07$, df = 1, p = 0.075). In total, 8 individuals exhibited multiple injuries out of the 18 injured individuals. Within the individuals with multiple injuries, a clear imbalance between males and females with multiple injuries (7 out of 142 males, 1 out of 118) was present.

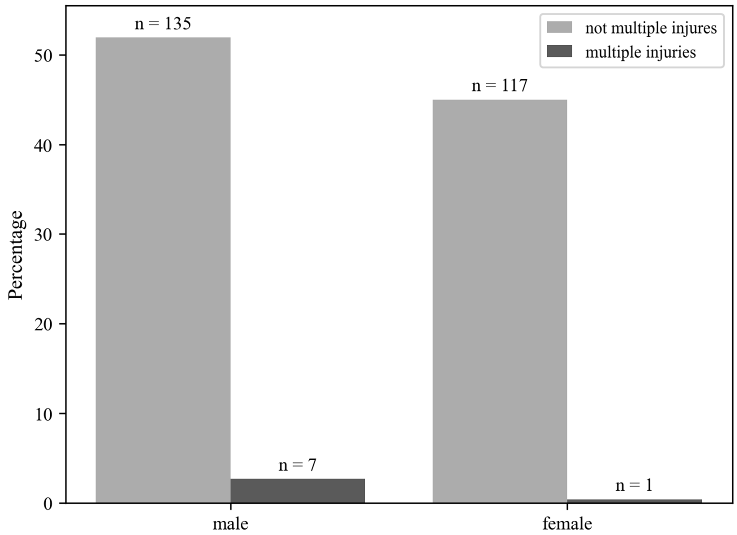

Figure 67: Distribution of multiple long bone injuries in males and females

In summary, the second hypothesis, stating that males have a higher prevalence of multiple injuries than females, could not be confirmed, possibly due to the small number of individuals affected.

Hypothesis 3: The third hypothesis, which states that the prevalence of injuries altogether is higher in older individuals than in younger individuals, was tested among the three age at death groups (young, middle, old adults). A significant difference was found ($\chi^2 = 9.44$, df = 2, p = 0.009), where the middle adults showed significantly more injuries (11 out of 18) than the young adults (4 out of 18) and old adults (3 out of 18) respectively. Figure 70 shows the uneven distribution of individuals with and without injuries, divided by age at death groups.

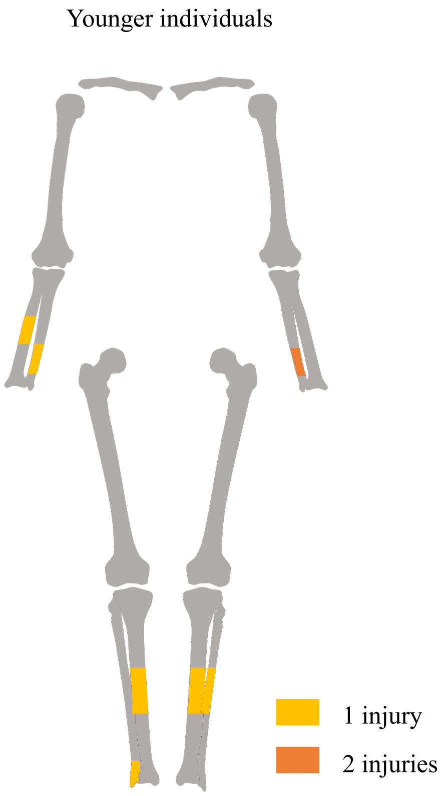

Figure 68: Summary of long bone injuries observed in younger individuals (< 35 years old at age at death). Light orange refers to one injury, dark orange refers to two injuries (made by A.Wagner)

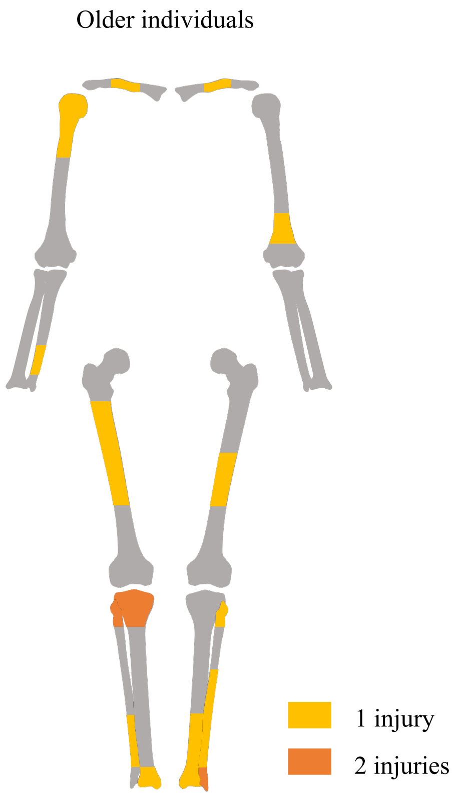

Figure 69: Summary of long bone injuries observed in older individuals (middle + old adults; > 35 years old at age at death). Light orange refers to one injury, dark orange refers to two injuries (made by A.Wagner)

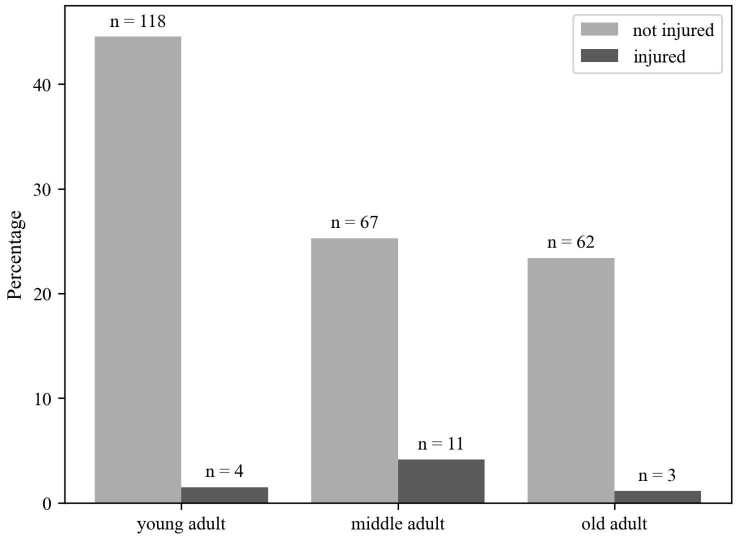

Figure 70: Distribution of long bone injuries in young adults, middle adults, and old adults

When the middle and old adults were combined, i.e., those who died after reaching 35 years of age, the older individuals had significantly more injuries ($\chi^2 = 0.312$, df = 1, p = 0.049) than the younger individuals (> 35 years).

In summary, the third hypothesis, stating that older individuals have a higher prevalence of injuries than younger individuals, was confirmed.

Hypothesis 4: The fourth hypothesis, which states that the prevalence of injuries altogether is higher on the upper extremity (clavicula, humerus, radius, ulna) than on the lower extremity (femur, tibia, fibula) was tested. There was a significant difference where more injuries were recorded on the lower extremity bones compared with the upper extremity bones ($\chi^2 = 0.393$, df = 1, p = 0.016). Of the 30 injuries recorded, 20 occurred in the lower extremities and 10 in the upper extremities, representing a clear imbalance.

In summary, the fourth hypothesis, which states that the upper extremity has a higher prevalence of injuries than the lower extremity, could not be confirmed. In the contrary, there is a significantly higher proportion of injuries in the lower than in the upper extremities.

7.5 Analysis of individuals with multiple injuries

Of the 18 individuals from Mödling - An der Goldenen Stiege who sustained injuries, eight of them exhibited more than one injury. The eight individuals presented either more than one fracture, more than one trauma, or both fractures and traumas. Of these eight individuals, seven were male and only one was female. The affected were comprised of two young adults, five middle adults, and one old adult. In total, the eight individuals exhibited twelve fractures and eight traumas. Table 18 lists the individuals with multiple injuries, their proximate cause, and whether they were concomitant.

Table 18: All injured individuals with multiple injuries listed with their serial number, grave ID, sex, age at death, type of fracture or trauma, proximate cause

Nr.	ID	sex	age at death	fracture/trauma	proximate cause
6	139	m	middle adult	oblique tibia fracture	indirect trauma
				oblique fibula fracture	indirect trauma
8	216	m	middle adult	soft-tissue injury on tibia	caused by fibula injury
				soft-tissue injury on fibula	crushed by fall or blow
9	229	f	young adult	soft-tissue injury on tibia	direct blow
				soft-tissue injury on fibula	direct blow
10	238	m	young adult	oblique ulna fracture	fall
				oblique ulna fracture	fall
				spiral/oblique tibia fracture	fall
				oblique fibula fracture	fall
12	261	m	middle adult	soft-tissue injury on tibia	accidental ankle sprain
				soft-tissue injury on fibula	accidental ankle sprain
15	343	m	old adult	impacted humerus fracture	
				soft-tissue trauma on humerus	fall
				oblique fibula fracture	fall
16	379	m	middle adult	tibia fracture	fall
				fibula fracture	fall
18	425	m	middle adult	soft-tissue injury on tibia	caused by fibula injury
				comminuted fibula fracture	crushed by fall or blow
				comminuted fibula fracture	crushed by fall or blow

Overall, there is a clear tendency for males to be affected more often by injuries in general, but especially by multiple injuries. Only one female exhibited more than one injury in contrast to the seven males out of a total of eight individuals. Most of the individuals with multiple injuries were middle adults (5 out of 8), and only two young adults and one old adult exhibited multiple injuries. All individuals who suffered from multiple injuries, sustained at least one injury to the tibia or fibula. The lower extremity, i.e., the tibia and fibula, were commonly affected. Most injuries were caused by indirect trauma, with falls as the likely cause. With the exception of one clear case in which the injuries were not concomitant and two ulnar fractures that were probably concomitant but for which it is not possible to determine, all other injuries occurred simultaneously.

8 Discussion

The aim of this thesis was to investigate the fracture and trauma patterns in the long bones of the adult individuals (> 17 years old) buried in the cemetery of Mödling - An der Goldenen Stiege during the Avar period. The tested hypotheses regarding differences in sex, multiple injuries, age at death, upper and lower extremities will be discussed as well as patterns related to how those injuries have been sustained, and how the people of Mödling cared for each other.

8.1 Preservation

An objective of this thesis was to record the state of preservation of the long bones of the burial ground of Mödling - An der Goldenen Stiege by assessing five segments (distal end, shaft with three segments, proximal end) separately. The shafts were mostly preserved and the preservation of the proximal and distal ends were similar, with either 0 or 2. Regarding the prevalence of injuries, many common injury sites were not represented due to poor preservation, e.g. distal radius and ulna fractures. The fact that the joints were often not preserved was problematic for the representation of trauma. Therefore, dislocations and fractures of the proximal and distal ends of the long bone would have been not possible to record. Of all the long bones, the fibula was the most poorly preserved, with the proximal and distal ends absent in about 70% of cases. Compared to the other long bones, the shafts of the fibula were also less well preserved.

The preservation status of skeletal remains can depend on different factors, such as the environment, including moisture, pH, access to oxygen, and temperature. External forces that can destroy or alter osteological material include fauna and flora with roots, rodents, or carnivores, but also the process of archaeological excavation itself (Henderson, 1987; Janaway et al., 2009). The deeper the burial, the more likely it is that the bones are more abundant and better preserved. Another consideration refers to the resistance of bone parts. Bones with low density, a higher proportion of cancellous bone and smaller bones in general, are more likely to be poorly preserved, which leads to a bias of the information available for a given skeleton (Bello et al., 2006). This phenomenon explains the difference in the preservation of the proximal and distal ends of the long bones as they have more cancellous bone compared to the shaft. The excavation of Mödling - An der Goldenen Stiege was a rescue excavation with many difficulties in terms of time and resources, as well as erosion and stagnant water in the graves that led to further taphonomic changes. Additionally, soil conditions were rather unfavourable due to intensive cultivation over the years, which led to the destruction of many graves near the surface (Marhold, 1977). It must also be taken into account that the excavation in Mödling - An der Goldenen Stiege occurred from 1967 to 1973 without the technology and resources of today's methods. This means that possibly some information about the burials and small objects and already damaged skeletal material was not documented and got lost. In the long bones, the state of preservation is usually less disturbed, with the exception of the joints, which are more susceptible to gnawing by carnivores and taphonomic changes. The above-mentioned factors all affect the representation of skeletal remains and thus the informative value of a skeletal series from a cemetery. Not only the demographics may be biased, but also the frequency of pathologies and trauma, as diagnostic features for assessment may be lost due to preservation (Waldron, 1987; Waldron, 2020).

Other cemeteries from the Avar period present different levels of preservation. For example, the skeletons from Vösendorf were described as mostly poorly preserved due to erosion (Pany-Kucera and Wiltschke-Schrotta, 2017). The skeletons from Leobersdorf was slightly better preserved but through systematic and more accurate methods, valuable information could be obtained from most of them (Pany-Kucera et al., 2022). Direct comparisons of frequencies for the state of preservation from other Avar period cemeteries are impossible because the recording methods differ. In most cases, the preservation status is only recorded descriptively.

8.2 Paleodemographic aspects

In this thesis, 265 individuals were examined for fractures and traumas. Originally, over 500 individuals were buried in the cemetery of Mödling - An der Goldenen Stiege during the Avar period. Because the interest of this study was to examine fractures and trauma in adults, infants, children, and subadults were excluded, resulting in a total of 298 eligible individuals. Due to sometimes too few bones or assessable features, the sex and/or age at death of 33 of 298 individuals could not be determined or given an age range of under 30 years and were therefore excluded. This means that this study is not representative of the Mödling cemetery in terms of demographic parameters, as only the sex and age at death of the adults included in this thesis are presented.

8.2.1 Sex and age at death

The individuals being studied consisted of 142 males (53.6%), 118 females (44.5%), and 5 individuals whose sex could not be estimated (1.9%), with significantly more males than females. The three assigned age at death groups divide the sample into 122 young adults (died between 17 and 34 years; 46.0%), 78 middle adults (died between 35 and 50 years; 29.4%), and 65 old adults (died after reaching 50 years; 24.5%). The young adults made up almost half of the sample, while the middle and old adults represent each less than 30% of the analysed individuals. Regarding the age at death distribution, it should be noted that 30 individuals were excluded because they did not have assessable characteristics related to age at death. They could represent either middle or old adults, which would either compensate for the uneven distribution, or make it more disparate with more young adults.

The age at death and sex distribution of other cemeteries from the Avar period point to different pictures concerning demography. The cemetery of Vösendorf with 138 males, 157 females, and 23 unsexed individuals present the opposite demography of Mödling with distinctly more females than males. However, 23 individuals were unidentifiable, indicating that the distribution between males and females was either more divergent or nearly balanced. When looking at the age at death span of the cemetery of Vösendorf, apart from the subadult individuals who made up over 30 % of the sample, mostly adults who died between the ages 20 and 29 with more females, adults who died between the ages 30 and 39 with males and females evenly distributed and mature adults (40-49) with more males were present (Pany-Kucera and Wiltschke-Schrotta, 2017). The burial ground of Zwölfaxing, where 208 skeletons were exhumed, included 129 individuals who died as adults, with 75 of them being males (57%) and 55 females (43%) (Szilvássy, 1970). This distribution of sex was rather similar to Mödling with a few more males than females. In Leobersdorf, 164 individuals, which were anthropologically and genetically sexed, included 56 males and 60 females. The sex distribution is almost even in contrast to Mödling, where more males than females were present (Pany-Kucera et al., 2022). The sex distribution of Leobersorf is similar to Kisköre, a Hungarian cemetery from the Avar period. In this cemetery, 209 graves were exhumed and 60 of the individuals were males and 64 females (Garam, 1979).

It appears that the burial grounds from the Avar period often contain similar proportions of adult males and females. Although the patterns discussed here may represent the general distribution of the mentioned cemeteries, there are limitations to compare them due to the subsample of the cemetery of Mödling - An der Goldenen Stiege. Apart from that, is it impossible to know if the skeletal remains represent the living population. Factors influencing the representativeness of an archaeological sample can include biases through burial practice, bone survival as well as age- and sex-specific biases (Bourbou and Pinhasi, 2008).

8.3 Differences in long bone injuries

The fractures and traumas recorded in this thesis from the cemetery of Mödling - An der Goldenen Stiege affected only 6.8% of the individuals and 1.0% of the 2992 examined long bones. Of the 265 individuals, 18 were injured and exhibited either a fracture, a trauma or both. In total, there were 19 cases of fractures and 11 cases of traumas. In the skeletal remains examined in this thesis, only antemortem and already very well healed fractures and traumas were found. This fact raises the question of whether there were no perimortem or postmortem injuries or whether none could be recorded due to the sometimes poor preservation and lack of assessable indicators. As mentioned in the results, mostly complete shafts of the long bones were available but both the proximal and distal end of the long bones were missing in many cases meaning, the ability to record trauma-related injuries specific to the joints was limited. Additionally, many of the already little preserved skeletal remains were eroded as well with little original bone surface left. It is possible that if the preservation of the skeletal remains would be better, the frequency of injuries may have been slightly higher.

8.3.1 Discussion of the hypotheses

Hypotheses 1 and 2:

The first hypothesis, stating that males show a higher injury prevalence altogether than females, was confirmed. The second hypothesis, stating that the prevalence of multiple injuries altogether is higher in males than females, was not confirmed. Both hypotheses are based on studies, which detected more aggressive behaviour and risk-taking in everyday situation in men than in women (Eagly and Steffen, 1986; S. Novak, 2017; Pawlowski et al., 2008; Standen and Arriaza, 2000). It has has been suggested that men take part in more hazardous occupations such as agriculture, forestry, or construction (Lovell, 1997). Differences in injury prevalence with males being affected more frequently reached a significant result. A total of 17 cases of fractures and 8 cases of trauma were recorded among the males of the Mödling cemetery. For females, there were a total of five injuries recorded, including two fractures and three traumas. It is evident that males were much more frequently affected by long bone injuries, especially fractures. The incidence of trauma was somewhat more evenly distributed between the sexes than that of fractures. Although, there were more cases of injuries than males were present, leading to the conclusion that an injured male likely sustained more than one injury, no significant difference was reached. In total, eight individuals exhibited multiple injuries with seven of them being male and only one female.

These results are consistent with findings in other trauma studies. For example, a study about three skeletal series from the Eastern Adriatic dated to the Late Antique, Early Medieval and Late Medieval period found that in both medieval series, males exhibit significantly higher fracture frequencies than females. However, in the Late Antique series, the fracture frequencies were rather evenly distributed. The authors attributed this result to the fact that in the Medieval period risks resulting from everyday activities were higher in men but during the Late Antique, women were an important part of the workforce and more equal in their laborious activities (Šlaus et al., 2012).

A British Medieval farming village presented a fracture frequency of 19.4%, with 33 of 170 individuals being affected, where males exhibited more injuries but the difference between the sexes was not very disparate and did not yield significant results (males 22, females 17). The fractures themselves were "indiscriminately distributed" between the sexes, but the types of fractures and their location suggest a division of labour and segregated activities. But both males and females in rural environments had higher fracture frequencies than in urban environments (Judd and Roberts, 1999).

In the Early Medieval site of Säben-Sabiona, Italy, trauma was observed in 29 males (78.4%) and 4 females (10.8%) with sharp force injuries exclusively being found in males. Apart from injuries caused by individual accidents during everyday and occupational activities, the trauma pattern also resembles the distribution of injuries obtained during close combat, which only males were affected by. The authors attribute these injuries, both unhealed and healed, to minor and sporadic but very violent conflicts (Tumler et al., 2019).

All of the results mentioned above paint a similar picture with males being more affected by injuries than females, however, how large the difference of injuries between sexes is depends on the circumstances and the living conditions. The reason for this trend of males sustaining more injuries can be attributed to several factors, including sexual division of labour with occupational hazards (i.e., agriculuture, animal husbandry, hunting, and farming), but also more aggressive behaviour, warfare, and risk-taking (Eagly and Steffen, 1986; S. Novak, 2017; Pawlowski et al., 2008; Standen and Arriaza, 2000; Lovell, 1997).

In conclusion, the first hypothesis, stating that males show a higher frequency of injuries, was confirmed and this result is in line with many other studies showing a similar trend of distribution of injuries between the sexes. However, the second hypothesis, stating that males also show a higher frequency of multiple injuries, was not confirmed. Still, seven out of the eight individuals showing multiple injuries were males and only one female.

Hypothesis 3:

The third hypothesis, stating that older individuals show a higher injury prevalence altogether than younger individuals, was confirmed. This hypothesis was based on the fact that older individuals accumulate injuries over their life time and are more prone to sustain injuries once they are older due to loss of bone mass (Judd and Redfern, 2012; Roberts and Manchester, 2010; Bennike, 2008; Cawthon, 2011). Systemic diseases, including metabolic disturbances, can make bones more susceptible to fractures. Osteoporosis, which weakens the bone through the loss of bone mineral density leads to an increase in fracture prevalence in old age and is currently a problem in modern western societies, with women being the most affected (Friedl, 2011). However, the distribution of injuries among the three age at death groups showed that the middle adults (35 to 50 years old) presented both the highest fracture frequency and trauma frequency (11 out of 18 injured individuals) and not the old adults over the age of 50 years. When looking at the distribution of age at death for the whole sample though, the middle adults represent only 29,4 % of the 265 (n = 78) individuals. When the age at death categories were divided by younger individuals who died before reaching 35 years of age and older individuals who died after turning 35 (middle + old adults) , the older individuals had significantly more injuries (14 out of 18 older vs. 4 out of 18 younger individuals).

Other studies, for example, an Early Medieval trauma study, show that there was a significant association between old age and higher trauma frequencies (Šlaus, 2008). Older individuals are more exposed to the risk of being injured as injuries accumulate over the course of a lifetime (Roberts and Manchester, 2010). For older individuals, injuries are more of a danger to their life in general, where a simple fall may lead to incapacitation, or death (Galloway and Zephro, 2005). However, it should also be considered that the bones of younger individuals have faster metabolic processes and higher levels of collagen, making them more flexible while also being able to heal faster. This phenomenon may lead to a bias in injury recording as well-healed injuries or greenstick fractures are not always possible to detect (Lewis, 2006).

This discussed trend of middle adults in Mölding sustaining the majority of the injuries seems rather unexpected and different from other studies from the Early Middle Ages that have shown that older individuals are more likely to suffer from fractures and trauma, especially antemortem injuries that accumulate over time and fractures secondary to ageing (Roberts and Manchester, 2010). However, some studies have found similar results where middle adults (in this case 31-45 years old) exhibited the majority of the long bone fractures with 19 of 29 fractures, where males had 24 and females 5. A different distribution was present in craniofacial fractures, where old adults (+ 45 years old) had a higher percentage of fractures than the middle adults. Most of the sustained injuries to the long bones were caused by accidents, but the craniofacial injuries were attributed to deliberate violence (M. Novak and Šlaus, 2012). These results suggest that older individuals from the Early Middle Ages sustained more injuries. However, older individuals have had more time to remodel their bones after an injury occurred due to their longer lives, resulting in a lower prevalence.

In the study of Pohansko and Břeclavi (8th to 10th centuries AD), where people were exposed to a low risk of trauma (long bone fracture frequency: 1.4%), most of the injured males were between 30 and 50 years old at age at death, whereas most of the injured females were over 60 years old at age at death. The injuries were almost exclusively attributed to accidents (Konásovà et al., 2009). This finding suggests that males sustained more injuries and died earlier either because of those injuries or with those injuries. Females sustained more injuries in old age due to factors such as osteoporosis.

In Mödling, there also may be a lack of age-related injuries in older individuals due to their greater bone strength and resilience through more physically demanding lifestyles while they were younger (Judd, 2002). There is a possibility that the older individuals of Mödling maintained a healthy diet and physical activity, meaning no tendency for age-related injuries occurred. However, as no other health and stress indicators were assessed in this thesis, no conclusion can be drawn as of now. Only one old adult showed accumulation of antemortem injuries which were probably caused by two different accidents. The other two old adults presented only a single injury, each one with a unique cause.

Another factor influencing the distribution of injuries between the age at death groups is that in the 78 middle adults, 55 males but only 22 females were present. As more middle adult males than middle adult females were present, it did not seem surprising that most of the injuries were in male middle adults as males are more likely to sustain an injury.

In summary, the third hypothesis, stating that the prevalence of injuries altogether is higher in older individuals than in younger individuals, was confirmed with individuals who died after turning 35 years old exhibiting the highest injury frequency.

Hypothesis 4:

For the fourth hypothesis, stating that the prevalence of injuries altogether is higher on the upper extremity (clavicula, humerus, radius, ulna) than on the lower extremity (femur, tibia, fibula), the opposite was confirmed. Originally, the hypothesis was based on the fact that the anatomical distribution of interpersonal violence injuries mainly affects the upper extremity (Brink et al., 1998), and many studies suggest that the upper extremity, mainly the ulna, is more affected by interpersonal violence (M. Novak and Šlaus, 2010; Šlaus et al., 2012). But also the radius and clavicula often break in an accident during a fall (Mays, 2006; Judd and Redfern, 2012). Here, the lower extremity was more affected by both fractures and traumas. Trauma-related injuries occurred almost exclusively to the lower extremity (20 out of 30), in contrast to the upper extremity (10 out of 30).

In other studies comparing the incidence of fractures in rural communities, the ulna and radius were the most commonly injured bones, with the upper extremity standing out as mainly affected (Šlaus et al., 2012). Two separate authors have reported that lower extremity injuries, mainly tibia injuries, are more common in modern day people than in archaeological populations with accidents involving playing football or falling due to terrain (Judd, 2004; Ortner, 2003a) .

In a British Medieval farming village, the upper extremity was much more affected with the most fractures occurring on the clavicula, followed by the radius. Although the upper extremity sustained more fractures, the fibula stood out with the most fractures on the lower extremity. The authors argued that the distribution of fractures in the rural British medieval site was "indiscriminately" between the sexes, but the types and locations of the fractures represent a division of activities and labour (Judd and Roberts, 1999).

A reason why the lower extremity in Mödling presented more injuries than the upper extremity might be caused by a preservation bias where the lower extremity is better represented. Significantly more bones of the lower extremity were present than bones of the upper extremity. Hence, besides an injury pattern of accidents, less injuries were possible to record on the upper extremity and information might have been lost (see Table 6).

Another reason why the upper extremity was less affected may have been the lack of interpersonal violence among the people of Mödling. After the head and neck, the upper extremity with the arms and hands was the most injured region in a recent medical study, with most of these injuries being incised wounds. Mainly these injuries were defensive wounds caused by stabbing, although some were attributed to attack wounds (Brink et al., 1998). The sharp force trauma interpreted as interpersonal aggression at Säben-Sabiona in Italy was either found on the upper extremity as defensive wounds, but also on the lower extremity to immobilise the opponent (Tumler et al., 2019).

However, there are three different cases in which, similar to Mödling, the fibula had the highest fracture frequency: Whithorn, Chichester, and Fishergate, all British Medieval cemeteries. In these studies, Medieval hospitals with similar injury patterns were analysed, with the fibula being prone to injury and less so the ulna and radius. However, the circumstances in which people were in poor health are quite different from those of the people from Mödling (Roberts and Manchester, 2010; Judd and Roberts, 1998).

As most of the affected individuals suffered from single, non-lethal fractures (10 out of 18 injured individuals), or multiple but also non-lethal fractures (8 out of 18 injured individuals), were these injuries more likely to be the result of accidents or single events of interpersonal conflicts but not of warfare. In warfare, fatal and most likely multiple injuries caused by sharp force trauma would be present (Harrod et al., 2012). The injuries resemble the injury pattern of Campochiaro (6the to 8th century AD) an Early Lombard-Avar cemetery in Italy, where the injuries were caused by weapons not related to everyday events or other accidents. The osteological material suggests a military nature with injuries to the head from weapons similar to Bynzantine gear, such as battleaxes and spiked maces (Rubini and Zaio, 2011).

The injury pattern in Mödling - An der Goldenen Stiege suggests accidents over interpersonal violence. Judd and Redfern (2012) suggest that the majority of long bone fractures are the result of accidental causes. As mostly the tibia and fibula are affected by injuries, accidental causes including slips and falls, fleeing an accident (or violence), direct blows in the form of blunt force trauma, and livestock-related injuries seem likely responsible. Although cranial injuries are more prone to be caused by violence, head injuries caused by falls or falling objects are possible as well and not represented in this thesis. In modern samples, tibial shaft fractures are common in men and individuals who are around 30 years of age. After the age of 70 years is reached, women exhibit dramatically more tibia shaft fractures. The fibula on the other hand is susceptible to fracture in older individuals, but also in athletes due to high-energy accidents (Galloway, 2013).

The frequency of fibula (10 out of 30) and tibia (7 out of 30) injuries was striking and unexpected, but most likely underscores the conclusion that people in Mödling suffered from accidents caused by their daily lives. The fact that many fibula fractures were single fractures and did not involve the tibia speaks for not severe accidents and that these fibula fractures were maybe caused by un/loading weight while trying to balance a fall. A study found that fractures of the lower extremities are likely to be caused by falls from the lower heights (1.5 m). Lower extremity fractures are commonly associated with low-energy falls in older individuals (Rowbotham et al., 2018).

The injuries of Mödling - An der Goldenen Stiege were attributed to a life with occasional accidents, with the lower extremity being mostly affected. This assumption also fits the period of the cemetery, where the people of the Avars most likely lived a life dedicated to agriculture, animal husbandry, and other daily activities (Pohl, 2018). However, it is possible that the victims of warfare where buried elsewhere in the vicinity of the battlefield. No signs of warfare were detected with healed injuries indicating violence of individuals who survived as veterans. Neither the associated settlement of Mödling - An der Goldenen Stiege nor other evidence of warfare has been found as of yet.

In summary, for the fourth hypothesis, stating that the prevalence of injuries altogether is higher on the upper extremity than on the lower extremity, the opposite was confirmed. Although the upper extremity did exhibit injuries (10 out of 30), the lower extremity showed significantly more (20 out of 30). Little evidence of violence has been detected and the injury pattern points more towards accidents with the tibia and fibula suffering most of the injuries.

8.3.2 Contextualising the findings across time and space: the literature on injuries in other cemeteries in Early Medieval Europe

Trauma-related analyses of the populations associated with Avar culture are limited and often are the injuries unsystematically recorded. A few cases of outstanding injuries, for example a middle adult female who suffered two fractures of the tibia with a twisting of the shaft and a torn ligament at the knee and due to lack of medical care, a right-angled stiffening of the knee (Szilvássy et al., 1984), are known from Avar cemeteries but little population-wide analyses are in existence as of now.

Table 19 lists a few cemeteries dated to the Avar period from the Carpathian Basin and presents their examined individuals, the frequency of injuries if available, how many individuals exhibited fractures and traumas, if the recording of trauma was systematic, and their archaeological dating. Included studies were designated as systematic if established methods for the recording of trauma were used (Lovell and Grauer, 2018, Judd and Redfern, 2012, Lovejoy and Heiple, 1981). However, not the same methods of dividing the long bones in 5 segments (3 segments on the clavicula) for preservation and location of injuries were applied in these studies. The injury prevalence of the mentioned cemeteries cannot be directly compared as they represent injuries on the entire skeleton, not just the long bones. Therefore, direct comparisons of injury frequencies are impossible. Table 19 illustrates the low injury frequencies among cemeteries from the Avar period.

Table 19: Comparison of injuries in other Early Medieval cemeteries associated with the Avar period

	N	Injury prevalence	Injured	Systematic recording	Dating
Mödling	265	6.8%	18	✓	630-720 AD
Csokorkasse 11	755	3%	22	✓	600-760 AD
Vösendorf	443	13.0%	47	✓	630-800 AD
Leobersdorf	164	17.1%*	28	✓	650-800 AD
Zwölfaxing	208	2.4%*	5	-	680-830 AD
Privlaka	188	13.2%*	26	✓	700-800 AD
Bruckneudorf	383	13.8%*	53	✓	700-900 AD
Szarvas	423	8.0%*	34	✓	700-900 AD

Systematic recording = the same established methods of trauma recording were used; * = injury frequency was calculated separately by the author; adapted from Pany-Kucera and Wiltschke-Schrotta, 2017; Großschmidt, 1990; Szilvássy, 1980; Pany-Kucera et al., 2022; Pany-Kucera and Wiltschke-Schrotta, 2023; Molnár and Marcsik, 2002

The Vösendorf cemetery showed that 13% of the 443 people had suffered fractures and most of them had healed well. Many fractures were caused by falls. The fractures were also unevenly distributed between the sexes, and the authors described the distribution as "men were slightly more frequently affected". However, many bones were also affected that are not considered in this thesis, such as the hand (Pany-Kucera and Wiltschke-Schrotta, 2017). In the Zwölfaxing cemetery from the Avar period, only five of 208 individuals had fractures. All affected were middle adults and mostly old adults, and had suffered antemortem injuries that showed signs of healing (Szilvássy, 1970; Szilvássy, 1980). Bruckneudorf, another cemetery in the Austrian part of the Carpathian Basin from the Avar period, has 383 anthropologically studied skeletons. Of the 207 adults, 117 were male and 81 female. At the postcranium, 39 fractures were found in the males and 14 in the females, affecting mainly the left clavicle and ulna in the males and the right ulna and radius in the females. The difference between males and females in terms of fractures is very striking and similar to that found in Mödling and other cemeteries from the Avar period. This different distribution of fractures at the postcranium compared to Mödling - An der Goldenen Stiege could be either due to different activities or partly to the better preservation of the skeletons from Bruckneudorf (Pany-Kucera and Wiltschke-Schrotta, 2023). The individuals from the Leobersdorf cemetery from the Early Middle Ages had mostly healed rib fractures, which were not comparable to this work. Interestingly, no fractures of the lower extremities were found in the skeletal remains, which is the opposite of Mödling (Pany-Kucera et al., 2022). A masterthesis on Leobersdorf was written in which the skull, ribs, and cervical vertebrae were examined for fractures. Of the 127 individuals examined, 19 (14.7%) had at least one fracture. Although statistical significance was not reached, males were more commonly affected, but older individuals (> 35 years old) had significantly more fractures than younger individuals (< 35 years old) (Mühlburger, 2023).

A study of skeletal remains from the Hungarian cemetery Szarvas of the Avar period revealed that out of 443 individuals 34 exhibited traumas, which would correspond to an injury frequency of about 8% (calculated separately by the author). The injuries were predominantly suffered by males due to possibly laborious activities (28 out of 34 individuals were male). Interestingly, in addition to many traumas, more degenerative changes were noted, especially in the vertebral column and extra-vertebral locations and especially in males, supporting the idea of a sexual division of labour among the Avar people. The authors also recorded many infectious changes, which they attributed to the deteriorating environmental conditions in the Late Avar period (Molnár and Marcsik, 2002).

Similar conclusions were drawn from the Privlaka cemetery in Croatia from the Avaro-Slavic period in the Early Middle Ages, where 26 individuals (18.1%) out of 144 adult individuals (n = 181) presented traumas. The injuries were evenly distributed with 14 out of 71 males exhibiting injuries and 12 out of 73 females exhibiting trauma. In contrast to the findings in this thesis, the upper extremity was more commonly affected. The higher frequency of trauma found in Privlaka has been interpreted as cases of interpersonal violence, but accompanied by an overall decline in health and availability of food resources. The later stages of the Avar period seem to have brought higher mortality with dietary deficiencies and physical stress, which were unevenly distributed among the population, though (Šlaus, 1996).

The individuals in the Csokorgasse 11 cemetery presented a very low fracture frequency of 3%. The author reported an increase in fractures in individuals from the Middle and Late Avar period compared to the Early Avar period but an overall decrease of degenerative diseases from the Early to the Late Avar period. This result was interpreted as an improvement in living conditions with enough food resources (Großschmidt, 1990). These findings oppose the results from Szarvas and Privlaka but possibly show regional differences in the life of the people associated with the Avars.

Another example from Croatia, but not associated with the Avar culture, presented distinctly higher trauma frequencies overall with 18.8% in the continental part and 36.5 % in the Adriatic part of the Early Medieval sample. The authors calculated long bone frequencies separately for the extremities with the result that in both males and females, the upper extremity was either significantly more affected or the traumas were distributed evenly among the extremities, in contrast to the results presented here. Since antemortem injuries were predominantly recorded and only a few perimortem injuries (in males), it was interpreted that most injuries were caused by accidents and falls, and that only a few males suffered fractures due to interpersonal violence (Šlaus, 2008).

All the mentioned cemeteries from the Early Middle Ages, although not directly comparable for the abovementioned reasons, showed in general a low frequency of injuries. If perimortem injuries were recorded, they usually involved the skull, which was not represented in this thesis. Generally, males were more affected by trauma, although the degree of difference varies. Often, the upper extremity was more involved in trauma than the lower extremity, opposing the findings here. Many of the mentioned authors suggest a peaceful sedentary lifestyle; however, with a turn for the worse in the late stages of the Avar period with more interpersonal trauma and health deterioration through the reduction of resources.

8.3.3 Breaking the fibula - accident related trauma?

The majority of the trauma-related injuries were concentrated on the lower extremity, namely the fibula while sustaining 10 of the 30 injuries. More than half of these were fractures (6/10). In comparison, the tibias suffered seven injuries, with only three of them being fractures. The true prevalence rate for the fibula heads was the highest out of all bone segments with 5.6% on the right fibula and 2.9% on the left fibula. The distal ends of the fibula presented higher rates of the true prevalence as well with 1.2% on the right and 2.7% on the left. Most of the injuries on the fibula were associated with an injury on the tibia as well, however not all fibula fractures were accompanied by a tibia fractures. As far as the preservation was concerned, Table 6 illustrated that the fibulas in this sample were not better preserved and therefore actually less available than other long bones. In fact, the preservation of fibulas was rather worse compared with the tibia. Therefore, the occurrence of injuries mostly on the fibula did not reflect a preservation bias. The sequence of injuries can hardly be retraced in multiple injuries if both have healed. However, since most of these injuries occurred at the same level and have a similar status of healing, it can be assumed that they were caused simultaneously by a single mechanism of injury. Single fibula shaft fractures are not a severe injury compared with tibia shaft fractures as they have less functional importance than the tibia and unite readily (Galloway, 2013).

Studies of Early Medieval cemeteries did not reveal a similar distribution of injuries, as in most cases, the upper extremity was more likely to be affected, especially the forearm. However, in some cases the fibula stood out with a high injury frequency, including Fishergate, Chichester, and Whithorn, all British cemeteries of the Middle Ages. Fractures of the clavicle and fibula were more common at Chichester Hospital than at other cemeteries, whereas fractures of the ulna, radius, and humerus were surprisingly rare. However, the high distribution of fractures is probably due to the unusual character of hospital cemeteries (Cardy, 1997; Stroud and Kemp, 1993; Judd and Roberts, 1998). In the medieval British cemetery of St.Helen-on-the-Walls, the fibula did not really stand out with many fractures compared to the ulna and radius. The authors argued that the most fractured long bones were the radius, ulna tibia and fibula with most them caused by accidents (A. Grauer and Roberts, 1996).

Even though the number of fractures on the fibula was uncommon, the type of fractures sustained not necessarily. An example would be the case of individual with grave ID 238, who sustained a tibia and fibula fracture almost at the same level, next to two ulna fractures. A very similar case was presented in a paper about a mature male adult in an Early Medieval cemetery from Nãdlac "Lutărie" (Arad County, Romania). He exhibited almost the same fracture lines with the fracture on the fibula being more proximal than the fracture of the tibia. Through healing, a distinct callus was visible together, with measurable shortening of the bone and shifting of the axis. The same circumstances apply to the individual here. The authors concluded that the lower extremity fractures (and clavicle fracture) were associated with a fall and mention that this case would fit a horseman because his grave goods would also support riding (Andreica, 2013). Here, it seems that a very similar injury mechanism was at work but the same cannot be concluded as the funerary inventory does not reflect any particular circumstances.

A case of fractured fibulas that was rather uncommon affected individual 425 with bilateral comminuted fibula head fractures and a soft-tissue injury on the tibia resulting from the fracture. Fibula head fractures are not common and can be caused by either stress on the knee or a direct blow (Chytas et al., 2010). In the literature, similar cases were sparse except for a paper with an individual sustaining bilateral fibula head fractures due to an epileptic seizure. This paper mentions that fibula head fractures are rather uncommon and are often caused by a direct blow or possibly stress on the knee (Rawes et al., 1995). Another paper mentions avulsion fractures on the lateral side of both fibula heads caused by a hit from a car on the anteromedial side of both knees. The fractures were due to avulsion of lateral collateral knee ligament and biceps femoris tendon (Chytas et al., 2010). In the case of individual 425, a direct blow may have been responsible for the bilateral fibula head fractures. It is possible that this case involved an event of interpersonal violence in which someone struck both fibular heads symmetrically at the same time or the person may have been crushed by an object on both sides, possibly an animal.

In summary, the fibula in Mödling - An der Goldenen Stiege presented an unusual high frequency of injuries compared to other populations from the Early Middle Ages. It has been suggested that fibula fractures are caused by rurally based activities such as labour for agriculture and due to rugged terrain (Djurić et al., 2006). This information supports the sedentary lifestyle of the Avars in the Middle and Late Stages of the Avar period. The people who sustained single fibula fractures most likely did not suffer from severe consequences compared to other lower extremity shaft fractures.

8.4 Intentional vs. accidental injuries and their probable causes

The injuries accumulated in the cemetery of Mödling - An der Goldenen Stiege were characterised as antemortem and had healed over the life time of the affected individuals.

Distinctions between intentional violence and accidents in the skeletal remains may not be straightforward and are not always possible to assess. The type of fracture sustained can help differentiate, such as an oblique fracture line indicating a fall or a transverse fracture line indicating direct trauma by a blow. This distinction does not have to apply to the real circumstances, though. An oblique fracture can be caused by a fall because of a push from another person. Problems arise when attempting to distinguish a well-healed fracture, as the remodelled bone and callus formation make it difficult to identify a fracture line. However, most fractures of the long bones can be interpreted as accidental (Ortner, 2003b). The following chapters will discuss the reasons and characteristics of violent and accidental injuries. However, the interpretation of how injuries were sustained may be different, even if an injury fits the criteria of an accident, the person could have been pushed and hence was a victim of malice (A. L. Grauer, 2012).

8.4.1 Indicators for violence

Violence implies an intention behind the act of hurting someone with physical force, with different intentions and meanings. It should be remembered that violence may also take the form of emotional, psychological, or sexual violence towards a person, which is not visible in the osteological material (Martin and Harrod, 2015). Violence can be interpreted as a social interaction to resolve inter- and intragroup tensions (Boucherie et al., 2017). The areas in which a person is attacked are usually not random but follow sociocultural patterns, with the head and neck being the most frequently affected. Possible reasons for this include the fact that head injuries are strategically easy to accomplish and can be very painful, but they are also symbolic and highly visible (Walker, 1997; Redfern, 2017). This means that the most representative area of interpersonal violence, the skull, is not represented in this thesis and therefore very few comparisons or conclusions can be drawn about violence in the cemetery of Mödling - An der Goldenen Stiege. However, strategic direct blows to the long bones leading to the immobilisation of the targeted individual, i.e., the opportunity to facilitate the killing blow, is not present in Mödling (Tumler et al., 2019).

A well-known indicator of violence in bioarchaeological interpretations is a parry fracture, where the arm is held in front of the face to defend against a direct blow. It refers to a fracture of the middle to distal third of the ulna shaft resulting from parrying a direct blow. The name parry fracture implies a distinct action of parrying and therefore conveys a specific injury mechanism (Lovell, 1997). The parry fracture is said to be one of the most poorly defined injuries and remains controversial in palaeopathological interpretations due to implications about social behaviour in past societies and interpersonal violence. This phenomenon is visible in many bioarchaeological studies as ulna shaft fractures get diagnosed as a parry or, in more recent terms, nightstick fractures without addressing the criteria (Judd, 2008; Lovell, 1997). A review of isolated ulnar shafts suggested that high-energy forces lead to a non-union or higher degrees of displacement rather than parrying a direct blow or a fall (Szabo and Skinner, 1990). The following ulna fractures will be discussed on the basis of the criteria described in the Methods (Chapter 6.4).

In this study, four ulna fractures were recorded. All of them were recognised as antemortem, showed a callus formation, angulation, and deformation. The ulna fractures affected the following individuals with their associated graves (Table 20): 122 with an oblique ulna fracture, 238 with two oblique ulna fractures, and 403 with a transverse ulna fracture. Therefore, only the ulna shaft fracture of individual 403 would meet the criterion of a transverse fracture line and position. The ulna presented no unalignment but only callus formation. It was impossible to determine if the radius was involved as the associated left radius was only partly preserved. The person was a female young adult. Even if this ulna fracture was to be characterised as interpersonal violence, this would be the only case of a parry fracture in the totality of the individuals studied.

Table 20: Criteria for parry fractures according to Judd (2008)

	No radial invol.	Transverse fracture	Below midshaft	Minor unalignment
Ind. 122	✓	-	✓	✓
Ind. 238 right	✓	-	✓	✓
Ind. 238 left	✓	-	✓	✓
Ind. 403	?	✓	✓	✓

Another possible violent act in the cemetery of Mödling - An der Goldenen Stiege may have been sustained by the male old adult from grave 312. This individual exhibited a soft-tissue trauma on the left femoral shaft due to a direct trauma, possibly a blow with a sharp object. If such a trauma occurred, the object, possibly a knife or axe, must have penetrated through the soft-tissues to the bone and caused an impression. Possibly a similar event may have happened to the young female adult of grave 229 with inflamed soft-tissue injuries on the tibia and fibula.

Violent acts have been recorded in a study on decapitation in Mödling - An der Goldenen Stiege, and three individuals were found with evidence of decapitation (Wiltschke-Schrotta and Stadler, 2005). One of them, individual 334, was also recorded in this study with a healed soft-tissue injury to the radius. It is clear that this injury was unrelated to the decapitation. He had horizontal cuts from behind on C6 and C7, which were probably caused by an axe from behind. C2 of individual 203 was completely severed and he had cuts at C1 and C2 as well from the same incident. The cuts were inflicted from the front when he was stabbed twice with a knife. Individual 485 had horizontal sharp cuts on C7 from behind, similar to 334.

The types of injuries recorded in the long bones suggest that most injuries were not attributed to violent activities. The long bones alone, without the skull, presented hardly any signs of violence. The analysis of the skulls of Mödling revealed about 30 injuries so far, with some of them being perimortem. The different varieties of violence, such as warfare, interpersonal violence, or domestic violence, are not distinctively represented in this thesis. The trauma patterns observed suggested neither large-scale nor small-scale face-to-face conflict with the lack of perimortem injuries and cuts to the long bones (Tumler et al., 2019). Interpretations of domestic violence, such as possibly a parry fracture in females, must take the surrounding context into account. Domestic violence is often interpreted as being perpetrated only by males despite growing research finding active female participation in certain circumstances, including polyamories relationships (Judd and Redfern, 2012). The findings above imply that violence was not a determining factor for injuries in the cemetery of Mödling - An der Goldenen Stiege.

8.4.2 Indicators for accidents

The distinction between intentional violence and accidents in the archaeological and osteological remains is not necessarily straightforward. Palaeopathologists have argued that accidents are the most common cause of fractures and traumatic injuries in archaeological samples, compared with intentional violence (Ortner, 2003b; Lovejoy and Heiple, 1981).

A very common reason for accidents is falling. The definition of a fall is an unexpected loss of balance that causes one to come on the ground (Nordstrom et al., 1996). If an individual presents fractures with different kinds of impact, it should be taken into consideration that these fractures were either unrelated or the person fell from a greater height and had a high-impact fracture on the lower extremities, for example, and fell further on the ground from there, for example, on their shoulder, which leads to a low impact clavicle fracture (Rowbotham et al., 2018; Rowbotham et al., 2019). Fractures at the level of the clavicle or lower extremities are often associated with falls, as the individual usually falls onto their shoulder or lower limb (Andreica, 2013). The two clavicula fractures in this study as well as the majority of the injuries on the lower extremities are likely to be caused by falls. Out of the 19 fractures, 12 were oblique, indicating that they were sustained through an indirect trauma. Under which these circumstances may have happened cannot be reconstructed, but in the following sections, a few possible factors will be discussed, including animals, farming, terrain, weather, and activity-related injuries.

An important fracture should be mentioned with regards to accidents and falling, the Colles' fracture, a transverse fracture of the distal radius in the metaphyseal region. It is placed 25-40mm proximal to the radiocarpal joint (Mays, 2006). In modern clinical studies, the Colles' fracture is described as one of the most common fractures due to either high-impact trauma in young adults or low-to-moderate impact trauma in older adults (Habeebullah et al., 2015). The reason for most Colles' fractures is a fall while using the hand as protection (Brickley, 2002). Another common cause for a Colles' fracture may be fractures secondary to diseases such as osteoporosis. The Colles' fracture is rather regularly reported in a skeletal series (Mays, 2006). However, in the case of Mödling, it seems rather strange that no Colles' fractures or other radius fractures were found. In part, this may be caused by the preservation as 57.7% on the left and 64.9% on the right side of the segment 4 of the shaft and 38.9% on the left and 40.8% on the right distal ends of the radius were not available. In comparison, the Vösendorf cemetery exhibited nine individuals with radius fractures (Pany-Kucera and Wiltschke-Schrotta, 2017), and five individuals with radius fractures were noted in the Bruckneudorf cemetery (Pany-Kucera and Wiltschke-Schrotta, 2023). This means that the radius fractures do occur in archaeological samples from the Avar period, but none were found in Mödling. Although preservation may be partly responsible, it seems unlikely that no radius fractures were recorded, as most fractures in the Mödling cemetery were due to accidents and falls.

8.4.3 Factors influencing the occurrence and patterns of injuries: activities such as farming, animal husbandry, irregular terrain, and weather conditions

To evaluate the influence of the Early Medieval living conditions in fracture aetiology, the daily lifestyle and activities of Avar life are necessary to be reviewed.

Animal interactions of all kinds can lead to casualties or even death for a wide variety of reasons. The keeping and handling of various animals can lead to hazards especially with horses, cattle, pigs, and dogs, and less frequently goats and sheep (van Delft et al., 2019; Wessels et al., 2019). Blunt force trauma and injuries involve cases where people have been kicked, knocked over, or trampled by large animals. Injuries caused by animal activity can be confused with injuries resulting from assault or postmortem damage, especially if the injury was not in the healing process. Sharp force trauma such as bites or cuts, are hardly preserved in the osteological remains as they tend to only affect the soft-tissue (Bury et al., 2012). Injuries caused by dogs are mostly due to bites, but may also include falls while trying to restrain the dog (van Delft et al., 2019).

Horse-related injuries are and were common and can be severe as horses weigh around 400 to 500 kg and can kick with one tonne of force (Weaver et al., 2017). Fractures and injuries associated with horses often occur because of a fall from a horse, most commonly resulting in upper extremity injuries but also lower extremity injuries. Three different scenarios can lead to injuries caused by horses: mounted, unmounted, and dis/mounting. Injuries can also be sustained while non-riding activities such as grooming, feeding, handling or saddling or even due to horse-related injuries due to other humans such as bad riding etiquette, or wrong use of equipment (Danielsson and Westlin, 1973; McCrory and Turner, 2005; Thomas et al., 2006; Carmichael et al., 2014; Gombeski et al., 2017). Horse riding requires a combination of skill, technique, and balance and the ability to handle an unpredictable animal (Majeedkutty and Khairulanuar, 2017). A study of Large Animal Related Injuries (LARI) found that injuries caused by cattle mainly involve the lower extremities, especially the tibia and fibula (Murphy et al., 2010).

Agriculture and forestry have the highest rates of falls, and they remain the leading cause of non-fatal injuries in agriculture today (Nordstrom et al., 1996). Agriculture was probably an important component of Early Medieval settlements in one form or another and included various tasks related to animals, animal-drawn implements and vehicles, silos and ladders, and harvesting and slaughtering (Judd and Roberts, 1999). In more recent times, males are more frequently affected by injuries sustained in agriculture and farming (Weaver et al., 2017). It can be assumed that this pattern is due to occupational hazards and similar to that of the Early Middle Ages, since in this thesis, too, it was mainly males who were affected. Due to a lack of evidence, it is difficult to say which activities involving animals and agriculture were common in Mödling. In Mödling - An der Goldenen Stiege, no evidence of agriculture was found due to the lack of settlement remains but animal husbandry seems to be evident as the animal bones in the graves were mainly domesticated animals (cattle, chickens, dogs, and sheep/goats)(Schwammenhöfer, 1976). However, it is impossible to infer on the importance of agriculture or animal husbandry from grave goods alone.

Another factor possibly affecting the number and type of injuries in a population may be the terrain and environment of the living conditions (Lovell and Grauer, 2018). Uneven terrain, including rocks, roots, and steep areas, may lead to more accidental falls as it is harder to balance out incoming forces. Climate and weather can also affect the likelihood of sustaining an injury, especially with regard to falls. The season of winter is to be highlighted as it can cause even more circumstances of falling with slippery surfaces and ice surroundings (Hayashi et al., 2019). It can be assumed that the landscape of the Early Middle ages was similar to the conditions today regarding the border of the Eastern mountains of the Alps and foothills into the plain. These elevations were a likely site for human settlements, and the landscape consisted mostly of unevenly wooded areas. This assumption is proved by the many archaeological finds present in Mödling - An der Goldenen Stiege going back 6000 years ago (Matzner and Mödling, 1977; Matzner and Mödling, 1977). Therefore, it seems unlikely that the majority of the injuries were caused by challenging terrain. It can be concluded that even though most of the injuries were probably due to accidental falls, it does not mean that the landscape but probably activities were responsible.

The fractures and traumas recorded in the cemetery Mödling - An der Goldenen Stiege mainly affected those who died as male middle adults. This difference in sustained injuries raises the question of which activities led to these injuries and why males were much more affected. Due to the limited knowledge on the Avar way of life, there is little evidence of the activities and work tasks. Laborious activities, such as farming, animal husbandry, and the production of textiles or tools may have been grouped, but could have been fluid among the sexes. Useful artefacts in graves do not necessarily reflect the subsistence activities of their owners, or sexual division of labour and gendered hierarchies, but could instead represent symbolic objects of those who remain (Gilchrist, 2012; Gero, 1991).

However, the authors of the study of the 7th-9th century Hungarian Szarvas cemetery argued for a clear division of labour between males and females, as 28 of the 34 injured individuals in their osteoarchaeological series were male. As not only the high frequency in males was striking, but also the localisation of the injuries seemed to indicate strenuous activities, they proposed that males engaged in different work-specific activities compared with females (Molnár and Marcsik, 2002). A very similar pattern was present in Mödling - An der Goldenen Stiege, with 14 out of 18 injured individuals being male. The sustained fractures in this thesis point to males being more affected by injuries caused by accidents, animals, or occupational hazards; however, no claims can be made about work-specific task as no other health markers and no entheses development were examined. Specific injury mechanisms cannot be determined from today's perspective, but the injuries sustained might reflect the risks of farming and being exposed to large animals.

8.4.4 Interpretation of the occurrence of multiple injuries in long bones and the rest of the skeleton

This chapter focuses on the occurrence of multiple injuries among the individuals of Mödling - An der Goldenen Stiege and shows the tendency for males to suffer from multiple injuries more frequently and how multiple injuries manifested in an individual. However, no significant result was reached when testing multiple injuries in males against females.

Of the 18 individuals with injuries to the long bones, eight of them sustained multiple injuries to the long bones. Males were clearly more affected, with seven of the eight individuals being male. Only one female sustained multiple injuries while exhibiting two trauma-related injuries. The affected individuals suffered more fractures (12 out of 20) than traumas (8 out of 20).

To gain a better understanding of how many and which injuries these individuals had sustained during their lifetime, the rest of the skeleton of every injured individual was examined as well. Table 21 lists 9 out of the 18 injured individuals from Mödling - An der Goldenen Stiege who exhibited other postcranial injuries, with six of them having already sustained multiple injuries to the long bones. All injuries to the long bones as well as to the other postcranial bones were antemortem and healed. Most postcranial injuries occurred on the hands, with the fifth metacarpal being the most commonly affected. In other cemeteries from the Avar period, a similar distribution of injuries with the hand being often affected occurred, for example, in Vösendorf (Pany-Kucera and Wiltschke-Schrotta, 2017).

In the framework of the HistoGenes project, the skulls of all individuals in Mödling - An der Goldenen Stiege were examined as well. Fractures and traumas to the skull were noted in fewer than 30 individuals (so far, analyses are in progress) with mostly dents and depressions on the skull. None of the affected individuals in this thesis with injuries to the long bones also sustained cranial injuries. Some of the other individuals showed perimortem skull injuries, leading to the conclusion that there may have been acts of interpersonal violence.

Table 21: All individuals with postcranial injuries in addition to long bone injuries are listed with their serial number, grave ID, sex, age at death, type of fracture or trauma, postcranial injury and complication

Nr.	ID	sex	age at death	fracture/trauma	postcranial fracture
6	139	m	middle adult	oblique tibia fracture	5th metacarpal fracture
9	229	f	young adult	soft-tissue injury on tibia	hole on lateral ilium
				soft-tissue injury on fibula	
10	238	m	young adult	oblique ulna fracture	rib fracture (rib 10 or 11)
				oblique ulna fracture	
				spiral/oblique tibia fracture	
				oblique fibula fracture	
11	258	f	middle adult	oblique fibula fracture	greenstick fracture 5th metacarpal
					greenstick fracture 4th metatarsal
					mildly collapsed 3rd metacarpal
12	261	m	middle adult	soft-tissue injury on tibia	5th metacarpal fracture
				soft-tissue injury on fibula	3rd metacarpal fracture
13	312	m	old adult	soft-tissue cut on femur	5th metacarpal fracture
14	334	m	young adult	soft-tissue injury on radius	decapitated
					ossified tendon spur at 4th metacarpal
15	343	m	old adult	impacted humerus fracture	3rd metacarpal fracture
				soft-tissue trauma on humerus	midrib fracture
				oblique fibula fracture	midrib fracture
18	425	m	middle adult	soft-tissue injury on tibia	5th metacarpal fracture
				comminuted fibula fracture	collapsed vertebra (L3)
				comminuted fibula fracture	

The eight individuals with multiple injuries made up almost half of the injured individuals in total. It appears that when an injury was sustained, multiple bones were affected by a similar type of injury with the tibia and fibula being mostly affected. Here the same question of sequence of injuries is raised again and what relation those injuries had to each other. Multiple injuries may have resulted more often from repetitive injuries than from a single event. In this study, examples for both multiple injuries caused by a single event (individuals 139, 216, 229, 261, 379, 245) as well as multiple injuries accumulated over the individual life span (individuals 238 and 343) were present. It has been suggested that the progression of multiple injuries leads to premature death. Individuals with multiple injuries in an ancient Nubian sample were found to be mostly male and around 35 years old at the age of death (Judd, 2002). Similarities to Mödling can be observed with young and middle adults making up six of the eight individuals with multiple injuries (e.g., individual 238 with four fractures).

8.5 Medical treatment in the Early Middle Ages with special reference to the injuries found in Mödling

The type of medical treatment available in the Early Middle Ages may have depended on economic and social status and occupation (Redfern, 2010). In the literary sources of the Early Middle Ages, the doctor is mentioned several times and possibly appeared as part of the law in disputes (Niederhellmann, 1983). Unfortunately, the Avars themselves are not known to have left written records. However, medical knowledge is one of the elementary needs of a society and therefore reinforces the need for a medical profession. In terms of medical treatments and surgeries, for example trephinations occurred in the Carpathian Basin throughout time, beginning in the Neolithic and were used during the Avar period as well (Niederhellmann, 1983, László, 2016; Bereczki et al., 2015). Written, as well as archaeological, sources of medical treatment can be found by examining grave goods and skeletal remains. Examples include tweezers, surgical knives, spatulas, chisels, files, and retractors (Schumann, 2009; Kjellström, 2010). A very well-known 'doctor's grave' found in Bingen, a Roman site (ca. 100 - 200 AD) shows that occupational graves, especially 'doctor's graves', were already established in the Late Antiquity (Como, 1925).

In the Mödling cemetery, three tweezers were found in two men's graves and one child's grave. The tweezers could be interpreted as someone who either had medical knowledge or as someone who had to be perceived as having medical knowledge (Curta, 2021). However, a pair of tweezers can be used for many purposes, which therefore does not allow any conclusion. In the Hungarian cemetery of Kölked-Feketekapu A, the tweezers were interpreted as "hair tweezers" and not for medical use (Kiss et al., 1996). Other authors interpreted tweezers as 'beard tweezers' for adult men (Lobinger et al., 2016).

Besides the archaeological finds, the well-healed injuries and reduced displacement indicate that the injured were treated and cared for. From the way fractures and diseases were treated, information can be indirectly deduced about how the people of past populations acted and cared for their injured (Pany-Kucera and Wiltschke-Schrotta, 2017). In the case of Mödling - An der Goldenen Stiege, the fractures were probably treated, most likely primarily by stabilisation, as there was little displacement and malunion. Since pain was part of every injury, it was and is the most common reason to seek out medical treatment and help. Different types of pain exist, depending on where the damage occurred, how severe it is, and how the person reacts to the pain. It is also important to remember that people suffer to different degrees for different cultural reasons. Pain was most likely a common factor in prehistoric environments without easy and constant access to painkillers. Because pain is both an objective assessment and an emotional experience, people's past perceptions of pain remain unknown (Kjellström, 2010).

8.5.1 Considerations for treatment of fractures of the long bones today and in the past

This chapter will briefly discuss a few aspects of possible treatments of long bone fractures with today's methods and what treatments were used in the past. A focus was placed on ulna shaft fractures, humerus fractures, and lower extremity fractures.

Parry or nightstick fractures, as they are commonly called in medicine, can be treated either surgically or non-operatively. It has been suggested that the ulna shaft fractures with more than five mm displacement should be treated surgically (Ali et al., 2019). In Mödling, the fractures were already healed but exhibited deformity and shortening. It can be assumed that the people of Mödling knew how to treat ulnar shaft fractures conservatively with immobilisation. For example, the young adult male from grave 238 sustained isolated ulnar shaft fractures on both sides at hardly different positions. Previously, it was determined that these ulnar shaft fractures did not meet the criteria for a parry fracture. In the medical literature, bilateral isolated ulnar shaft fractures are uncommon. A case report presented bilateral ulnar shaft fractures resulting from an assault that required surgery with open reduction and stable internal fixation (Mahajan et al., 2021). If the fractures of the young adult from grave 238 were caused by a single traumatic event, the medical treatment had to be excellent to obtain such well-healed fractures.

Among upper extremity fractures, humeral shaft fractures can be treated either conservatively with immobilisation of the fractured arm in a 90-degree position for about 11 weeks or surgically, leading to a shorter duration of immobilisation and incapacity to work and more comfort (Strohm et al., 2011). A complication following humerus shaft fractures may be accompanying radial nerve palsy (Cowling, 2019). The individual 94 exhumed at Mödling, who died as a male middle adult, presented a comminuted humerus shaft fracture with clear signs of healing, care, and treatment. It was assumed that with this degree of bone remodelling and flattening of the bone, the fracture had to have been severe and possibly open. Therefore, treatment would have been difficult, and the probability of infection was high. It can be assumed that the person was cared for with the humerus immobilised and precautionary measures were used to handle the infection.

Lower extremity fracture treatment today, depending on the injury, varies and mostly involves operative measures (Althausen and Hak, 2002). Conservative methods of treatment exist, involving the immobilisation of the leg after. (Karladani et al., 2001). Most of the lower extremity fractures in Mödling show signs of deformity and shortening of the bone, but this does not mean that they were not treated. It can be assumed that most of them were immobilised because the load on the injured leg was most likely painful. Additionally, an uncertain case of distal fibula amputation was observed in individual 28. If an amputation was performed, it can be assumed that an operation was necessary possibly due to a trauma-related event with a spreading infection that could not have been stopped otherwise. Although the reason for this possible amputation is not known, this case gives insight into the medical knowledge and skills of the Early Medieval period.

With the information provided above, it seems likely that many injuries were possible to treat with conservative methods of immobilisation in the Early Middle Ages. Written sources going back to 1600 BC mention splinting and the reduction of shaft fractures (Cowling, 2019). Paul of Aegina, a Bynzantine medic, differentiated fracture types (Brorson, 2009). Later, in the Bynzantine period, the methods of Hippocrates were refined and modified (Clark, 1937). The Avars, influenced by the Bynzantine culture, may have known and used similar methods for treating humeral shaft fractures as well as other injuries. Regarding fractures to the lower extremity, Hippocrates suggested longitudinal traction to solve the overriding of fracture fragments (Hernigou et al., 2016).

This information indirectly gives insight into if and how past people cared for their injured regardless of the means. It is certain that treatment and care were available in Mödling. People treated their injured, possibly with the methods mentioned above or with treatments not known today, and took care of them, even if it meant that they could not work and contribute to their community.

8.5.2 Complications and impairment following fractures and traumas

Besides the pain that ensues when being affected by an injury, other complications will follow as well. These complications can be biological, that respond to the physical impact of an injury, psychological, dealing with the psychodynamic factors and social with external factors such as support from family and friends, financial support, or following changes in the workforce due to the injury (Singaram and Naidoo, 2019).

Biological complications can vary on how impactful they are on the affected individual, with death being the most serious. Next in line would be non-union, which occurs when a fracture does not heal (Waldron, 2020). However, a distinction needs to be made between a non-union and a delayed non-union, which means the fracture was not healed in the time expected, leading to the conclusion that the fracture did not have enough time to heal (Roberts and Manchester, 2010). During this complication, a fibrous joint may be created between the broken ends called pseudoarthrosis. In the archaeological record, this is often seen in forearm fractures, probably due to struggles with immobilisation (Lovell and Grauer, 2018). Neither death nor non-union was recorded as a complication of long bone injuries in any of the 18 injured individuals analysed herein.

However, malunion, i.e., shortening and deformity, were recorded in many individuals who suffered injuries. This complication may occur if a broken bone is not correctly reduced (Lovell and Grauer, 2018). Despite shortening or deformity of the bone, injured limb may still be functional, possibly with some difficulty and pain. In this thesis, deformity and shortening were recorded for the individuals with grave IDs 89, 50, 238, 139, 403. All injuries are susceptible to infection, with open fractures being the most vulnerable. Different organisms may infect a wound and lead to osteomyelitis (Lovell and Grauer, 2018; Waldron, 2020). In this thesis, many of the fractures and traumas presented remains of periosteal reaction, which may have been due to infections. Individual 379 suffered from two fractures on the tibia and fibula, which were infected to the extent of osteomyelitis with a cloacae at the malleolus medialis. Another example would be individual 94, who sustained a comminuted humerus fracture, which may have been open and probably lead to an infection and possibly to osteomyelitis. Another likely complication of injuries may be osteoarthritis, which can occur due to two circumstances. Either a poor alignment follows after a fracture heals, leading to altered mechanics of the associated joint or if the sustained fracture involves or extends to a joint. As osteoarthritis will develop over many years, it serves as an indicator of how long the individual has survived the injury (Waldron, 2020). Individuals 89 (clavicle) and 425 (both fibula heads fractured) present signs of osteoarthritis in the associated joints, hinting to a long survival after the fractures had occurred. Soft-tissue injuries include damage to the muscles, organs, blood vessels, and nerves. Peripheral nerves can be particularly prone to damage, such as the anterior and posterior interosseus nerve following injuries to the forearm (Waldron, 2020). An example from this thesis may have been individual 334 with the soft-tissue injury on the radius shaft. If an injury was not treated accordingly, prolonged immobility can be assumed (Singaram and Naidoo, 2019).

Injuries mean impairment for some time and limitations in activities (Judd and Redfern, 2012). Daily activities, including personal hygiene and eating, may be restricted by upper extremity fractures. Lower extremity fractures may lead to the inability to perform activities involving occupational tasks and mobility. These impairments would lead to occupational and financial difficulties. Psychological and social impacts on their lives, such as depression, anxiety, and post-traumatic stress disorder may appear. A fracture, especially of the lower extremities, may lead to the prevention of previously normal socialising activities (Singaram and Naidoo, 2019). An injury can result in complete or partial loss of mobility, changes in the way of walking, limited range of motion, pain, or discomfort (Gilmour et al., 2019). A person's life can end suddenly, or their quality of life can be severely affected, either temporarily or permanently (Judd and Redfern, 2012). It should be remembered that a long bone fracture takes on average about 4 to 6 months to heal (Lovell, 1997; Neri and Lancellotti, 2004). People with fractures may adopt resilient responses to maintain mobility, possibly to move independently (Gilmour et al., 2019).

In summary, although some of the long bone injuries from Mödling - An der Goldenen Stiege were deformed to varying degrees or infected, signs of treatment and care for the injured were present. The will to take care of a person is clearly shown by the long completed healing processes of most of the injuries, indicating a long survival after the injury, together with the willingness to offer resources and time, even if the person does not contribute to the community, and to give them what they need. This phenomenon is clearly seen, for example, in individuals 50, 94, 139, 238, 343, and 425, where serious injuries affected their quality of life at least temporarily, but probably permanently, and they were cared for despite their limitations. What is not seen here in the archaeological record would be medication, in whatever form we do not know today, to treat wounds as well as to relieve pain to alleviate suffering.

8.6 Reflections on various aspects affecting the life of the Avars

In the last chapter, various aspects of the archaeological remains and the people of the Mödling cemetery are discussed, which should provide a better insight into the Avar period and the life and death of the people in the Early Middle Ages.

8.6.1 Social status, grave goods and animal bones

The layout of the cemetery of Mödling - An der Goldenen Stiege and the buried grave goods can be assessed from different perspectives. One of them is the placement of the graves in connection with their archaeological dating. As described in the results, the distribution of injured individuals according to their archaeological dating showed no significant differences where most individuals with injuries were dated to MA (61.1%), followed by SPA (22.2%) and SPA I (16.7%). This result was not surprising, as this distribution nearly matches the distribution of individuals overall, with MA being the most represented. Thus, as more people were buried during the MA, there were also more injured individuals. The results indicate a pattern of decline over time for all persons buried in Mödling.

However, the question arises whether the injured were buried in close proximity to each other and thus had their own place in the cemetery, or whether the dead were possibly buried according to other factors, such as social status or family affiliation. Figure 71 shows the arrangement of graves in the cemetery of Mödling - An der Goldenen Stiege, with the recorded injured individuals marked in red. No real grouping can be detected throughout the cemetery, with the exception of individuals 112 and 139, who were buried next to each other. Individuals 229 and 238 were buried in the same grave on top of each other. Individuals 253 and 263 were also buried on top of each other in another grave. Therefore, the injuries were not a determining factor in the placement of the burial. This might have been different if the injuries sustained were the result of a single (violent) event. Furthermore, the three decapitated individuals (203, 334, 485) were also not in close proximity to each other, but in fact were in completely different parts of the cemetery. No conclusions can be drawn at this time about family relationships, injuries, and their role in the burial, but this will be investigated further as part of the HistoGenes project.

Another factor that may shed light on the lives of the people buried in Mödling are the grave goods as well as the placement of the buried in the grave by those who remained. Customarily, the deceased were placed in the grave in a supine position, along with objects that may reflect the needs of the dead, such as the widespread custom of using animal bones as grave goods (Distelberger, 1999). The site and finds of Mödling - An der Goldenen Stiege reflected the variety of forms of the finds characteristic for Avar cemeteries with more than 4000 objects found (Schwammenhöfer, 1976. Grave goods consisted mostly of pots, animal bones, arrowheads, spindle whorls, knives, and jewellery (Daim, 1976). Although many graves represent "gender-specific" components (e.g., spindle whorls for women, arrowheads for men), some objects, such as jewellery or tools of daily living, were

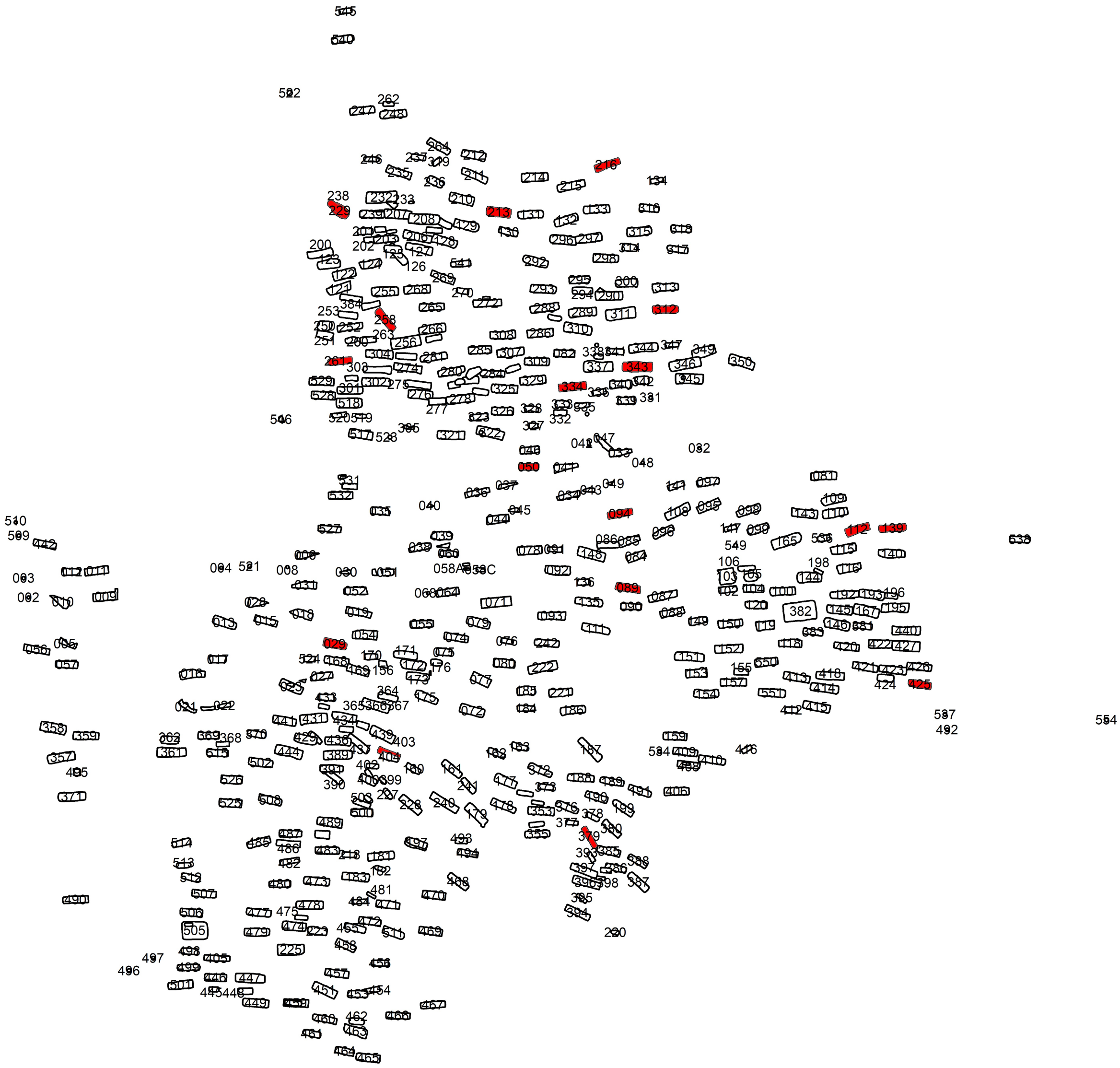

Figure 71: The cemetery of Mödling - An der Goldenen Stiege: red coloured graves represent injured individuals (adapted from Bendeguz Tobias)

used by all (Distelberger, 1999).

Overall, most of the individuals, injured and not, had animal bones in their graves mainly consisting of chicken, dog, cattle, and sheep/goat bones. Less present were pigs and geese bones, and only a few isolated red deer and horse bones were present. No horse burials were found in this cemetery and only three isolated horse bones were present. The injured individuals had mainly one cattle bone, one or two sheep/goat bones, and many chicken bones in their grave. Of the 18 individuals, six had no animal bones in their graves (graves 89, 139, 216, 229, 258, 312), with five of them being male. In past publications, the people of Mödling were mainly interpreted as sedentary people with an emphasis on animal husbandry, since only animal bones and no agricultural tools were found (Schwammenhöfer, 1976). However, as no settlement remains were discovered as of yet, no straightforward conclusion can be drawn about agriculture or animal husbandry. No agricultural tools or certain animal bones in graves cannot provide insight into the subsistence economy of a community as they represent selected items intended only for burial rites. Overall, animal bones tend to be more represented in the cemeteries of the 7th and 8th century in the Northeastern part of the Carpathian Basin (Baron, 2018). In comparison, in the Leobersdorf cemetery, more than half of the graves contained animal bones. In Leobersdorf, cattle predominated over chickens, while in Mödling, chicken bones were the most common. The composition of the animals offered as grave goods of Mödling suggests that since pigs and chickens were included, people have adapted their animal husbandry to local customs, as it was common for the Romans to keep pigs (Daim, 1987). This also suggests a less nomadic lifestyle and a more permanent sedentary life.

Of the individuals studied in this thesis, two had no grave goods at all (229, 258). Individual 229, a young female adult with soft-tissue injuries at the distal end of the tibia and fibula shaft with extensive inflammation and bone remodelling (as well as a hole in the ilium, possibly an arrowhead injury), was placed in the pre-existing burial of 238 from MA I (young male adult with four fractures). The grave of the young female 229 was deviating from the original shape of the grave and mostly disturbed and ransacked. Individual 238 had only two snail shells as grave goods and was in a squatting position. The other grave without grave goods was 258, a female middle adult with an oblique fibula fracture at the distal end of the shaft. The individual was placed 30 cm above in an existing but probably robbed grave of 263 (Distelberger, 1999). The burial context of the three decapitated individuals was quite different depending on the individual with a poor burial (203), a "lower class" burial (note by P.Stadler, 485) and a richer burial (334; Wiltschke-Schrotta and Stadler, 2005).

Individuals 229 and 258 both were placed secondary to an already existing grave without customary grave goods. Additionally, both were female and dated to the Late Avar period. Generally, graves with no grave goods were more common in females, while males more often had richer graves and sometimes these were even positioned next to each other (Distelberger, 1999). In his dissertation, Distelberger argues that in the later stages of the cemetery, namely SPA I, less grave goods than in the Early and Middle Avar period were recorded. With the phenomenon of burials in an already existing grave with some of them in a squatting position, it leads to the assumption of uncertainty and change in burial rites.

In summary, it appears that the injured persons themselves were not buried in any particular way. This finding is not surprising since the injured all survived their injuries for at least a few months, and in most cases years, and were not the result of a single event. What and how many grave goods were placed in a person's grave, as well as the placement of the body and the type of grave, may have had different reasons. However, during the use of this cemetery, more and more unconventional and poorer graves seem to appear, supporting the idea of uncertainty and change in the last phases of the Avar period.

9 Conclusions

The aim of this thesis was to document and interpret fractures and traumas in the long bones of the adult population (< 17 years old) in the cemetery of Mödling - An der Goldenen Stiege, dated to the 7th and 8th centuries (n = 265) with a focus on differences in the type of injury and who was affected. The people of Mödling presented low frequencies of fractures and traumas of the long bones (6.8%) suffered throughout their life and which had healed long before they died. Males were significantly more affected by injuries than females but no significant difference was reached for multiple injuries between the sexes. Although only antemortem injuries were noted, older individuals exhibited fewer injuries than middle adults ones, contrary to expectations. The lower extremity exhibited a significantly higher frequency of injuries than the upper extremity. The locations and types of injuries, with oblique fractures being more frequent, reflect a peaceful community with most injuries caused by accidents or occupational hazards. If a person in Mödling, more often a man than a woman, was injured during their lifetime through rural activities, the likelihood of multiple injuries either from the same event or at different stages of life, was high. Although no signs of medical equipment were found in the Mödling cemetery, traces of treatment and care were clearly present as severe injuries had healed well and were probably treated at least with immobilisation, suggesting that individuals who may have been bedridden for months and unable to serve their community were cared for. The changes in the Early Middle Ages towards more permanent settlements with a peaceful life including agriculture and animal husbandry among the Avars in Eastern and Central Europe fit the results of this thesis.

10 Limitations

This chapter illustrates the limitations of this thesis and the study of trauma in archaeological remains. Several limitations are present in this thesis.

First, although over 500 individuals were buried in the Mödling - An der Goldenen Stiege cemetery, 298 were examined but only 265 were included in this thesis. Due to the sometimes poor state of preservation and lack of availability of certain parts of the skeleton in some cases, the actual sample size was much smaller than the overall sample size.

The state of preservation of the skeletal remains certainly limits the informativeness in terms of the presence of injuries. Fractures and disarticulations at the joints, which were less well preserved than the shafts of the long bones, were particularly limited. The osteological material of Mödling has suffered from taphonomic forces, such as erosion, agricultural use, water damage, but also grave disturbances. The injury prevalence is possibly underrepresented because younger individuals exhibit fewer injuries because they are more resilient, but also because well-healed injuries may not be detected macroscopically or on radiographs (Roberts and Manchester, 2010).

Only the long bones of the postcranium of adults over 17 years of age were examined (clavicle, humerus, radius, ulna, femur, tibia, fibula). The skull and the rest of the skeleton of the injured subjects were also examined to obtain an overall picture, but were excluded from the statistical analysis. Specific injury patterns, such as interpersonal violence being detected through fractures to the hands, were impossible to record in this thesis. The results presented here only refer to a specific sample size and the whole population would likely reveal higher frequencies of injuries. However, generally, the injury prevalence of recorded injuries in a population is usually an underestimation (Djurić et al., 2006). It is hardly possible to distinguish what was the ultimate cause of an injury caused by blunt force. Although most of the recorded injuries have been assigned to accidental causes, it is impossible to reliably distinguish between intentional or accidental causes. When recording trauma, there is a possibility that pathological conditions may be mistaken for injuries, as they mimic traumatic events on the bone (Bennike, 2008).

Informative comparisons with other studies of human remains, particularly long bones associated with Avar culture, are limited due to the lack of studies available to date.

11 Future directions

Many new insights will be gained through the HistoGenes project, which integrates anthropological, genetic, archaeological, and historical resources in Eastern Central Europe, mainly the Carpathian basin, from 400 to 900 AD. The new results will shed light on the genetic sex of the individuals, archaeological dating by radiocarbon dating, genetic insights into family affiliations in the cemetery, and migration. All these findings will be taken into consideration to find diachronic relationships and connections in the Carpathian Basin during 400 to 900 AD. Within the framework of the HistoGene project, the recording and comparing of injuries of the the whole skeleton injuries of Mödling as well as other osteological material associated with the Avar period will lead to a better understanding of the Early Medieval people of the Carpathian Basin.

12 Appendix

12.1 Description of the individuals with uncertain cases

In the appendix, four individuals will be discussed with uncertain cases. Due to lack of assessable features or unclear conditions, it was not possible to diagnose these cases. One unclear case of distal fibula amputation (grave 28) was observed, but due to uncertainty about a trauma-related incident and authenticity, it is only mentioned but not included in the statistical calculations.

InvNr 27815, Grave ID 140: a male who died as middle adult

The right fibula shaft showed a curved axis of the proximal end of the shaft. Both fibulas were very eroded, and dirt was inside the bone, which made the examination more difficult. There was no fracture line apparent. Potential shortening of the bone was not possible to determine. Bowing and Greenstick fractures were considered but no conclusion was possible.

Figure 72: InvNr 27815, Grave ID 140: bent fibula (photographed by A.Wagner)

InvNr 27828, Grave ID 154: a male old adult

The right tibia exhibited a hole on the inferior articular surface. Osteochondrosis dissecans was considered as a diagnosis but could not be determined. Another answer would be that the hole was an unexplained variant.

Figure 73: InvNr 27828, Grave ID 154: hole on inferior articular surface of the tibia (photographed by A.Wagner)

InvNr 27908, Grave ID 247: a male who died as young adult

On the right fibula was a distinct thickened area around the middle of the shaft and on the distal end the bone seemed thinner and curved. The compact bone was not disturbed or interrupted. Deformation or shortening was impossible to determine as both fibulas were not completely preserved. Both tibias seemed symmetrical twisted and robusticity markers around the soleal line on the posterior side. A possible diagnosis may have been a Greenstick fracture.

Figure 74: InvNr 27908, Grave ID 247: bent fibula (photographed by A.Wagner)

InvNr 27930, Grave ID 269: a male who died as middle adult

Both humeri from this individual appeared to be curved. There were no signs of trauma or a fracture line visible on the bone itself or the x-ray image. It was impossible to determine shortening or deformity of both humeri as they were not entirely preserved. The claviculas of this individual were short and thick with very pronounced muscle markers. The right clavicula seemed shorter than the left. The sternum was twisted and bent but hard to determine because of postmortem damage. A Greenstick fracture was considered, however, as both humeri were symmetrical it would be unlikely but not impossible to exclude. Bowing may have been responsible, such as prenatal bowing or birth trauma, but the abnormality would normally rectify itself during the normal bone growth process due to the plasticity of the cartilage model. Prenatal bowing, birth trauma, other malformations, or abnormal muscular skeletal markers, should have been present as well. Bowing as a result of trauma would have called for fracture with deformity while healing (Stuart-Macadam et al., 1998).

Figure 75: InvNr 27930, Grave ID 26: bent humeri (photographed by A.Wagner)

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Fundkomplex	Grabnr.
Bemerkung	

Geschlechtsbestimmung:

Merkmal	Gewichtung G	Wert W	WxG
Calvarium			
Glabella	3		
Arc. superciliaris	2		
Tub. frontalia u.pariet.	2		
Inclinatio frontalis	1		
Proc. mastoideus	3		
Rel. d. Planum nuchale	3		
Protub. occ. ext..	2		
Proc. zygomaticus	3		
Os zygomaticum	2		
Crista supramast.	2		
Margo supraorbitalis	1		
Form der Orbita	1		
Mandibula			
Gesamtaspekt	3		
Mentum	2		
Angulus	1		
Margo inferior (M2)	1		
Winkel	1		
Pelvis			
Sulc. praeauricularis	3		
Inc. isch. maj.	3		
Angulus pubis	2		
Arc. composé	2		
Os coxae	2		
For. obturatum	2		
Corpus os.s ischii	2		
Crista iliaca	1		
Fossa iliaca	1		
Pelvis major	1		
Auricular area	1		
F.acetabuli/ Femurkopf	1		
Sacrum	1		
Langknochen - Robustizität			
Humerus	1		
Femur	1		
Σ			

Becken Bruzek (2002)	Sulc.Pr. Inc. isch. Arc. comp. Ramus pubis Ischium/Pubis	_ _ _ _ _ _ _ _ _ _ _ _ _	

Notizen:

Altersbestimmung:

Kombinierte Methode (Ascádi & Nemeskéri 1970)				Phase
Facies symphysialis (1-5)				
Femur spongiosa (1-6)				
Humerus spongiosa (1-6)				
Endocran.Nahtverschluß				
S1:	S2:	S3	S4:	
C1: /	C2: /	C3: /		
L1: /	L2: /	L3: /		
Geschätztes Alter: (Sjovold 1975)				

Zahnabrasion (Brothwell 1981)		
Ok M1:	Uk M1:	Alter:
M2:	M2:	
M3:	M3:	

Fac. symphysialis (McKern&Stewart 1957/ Suchey&Brooks 1990)	
Phase:	Alter:

Ectocranialer Nahtverschluß (n. Rösing 1977)				
S1:	S2:	S3	S4:	Alter:
C1: /	C2: /	C3: /		
L1: /	L2: /	L3: /		

Clavicula: Fac. art. sternalis (Szilvássy 1977)	
Phase:	Alter:

Epiphysenschluß (n. Wolff-Heidegger 1954)

Zahnentwicklung (n. Ubelaker 1978)

Diaphysenlänge (n. Stloukal & Hanáková 1978)		
Hu:	Fe:	Alter:
Ra:	Ti:	
Ul:	Fi:	

Degen. Veränderungen (n. Stloukal et al 1970, 1975)	
Wirbelsäule:	Fac. glen.:
Fossa acet.:	gr. Gelenke:

Zusammenfassung

Die Untersuchung von Traumata kann Einblicke in das Leben und den Tod einer Person und einer Gemeinschaft bieten. In dieser Arbeit wurden die Langknochen (Clavicula, Humerus, Radius, Ulna, Femur, Tibia, Fibula) der erwachsenen Individuen (> 17 Jahre alt), die im Gräberfeld von Mödling - An der Goldenen Stiege in Ostösterreich begraben sind und aus der Awarenzeit des 7. bis 8. Jahrhunderts stammen, auf Frakturen und Traumata untersucht. Insgesamt wiesen 18 Individuen (6,8%) antemortem Frakturen und Traumata auf, was zu 30 Verletzungsfällen führte, die sich auf 2992 Langknochen (1%) verteilten. Männer waren deutlich häufiger von Verletzungen betroffen als Frauen: 14 verletzte Männer gegenüber 4 verletzten Frauen. Obwohl Männer auch mehr Mehrfachverletzungen aufwiesen (7 Männer von 8 Personen mit Mehrfachverletzungen), wurde kein signifikanter Unterschied festgestellt. Ältere Personen hatten deutlich mehr Verletzungen, wobei mittlere Erwachsene (35-50 Jahre) die höchste Verletzungshäufigkeit aufwiesen. Entgegen der Erwartung, dass die obere Extremität (Clavicula, Humerus, Radius, Ulna) stärker von Verletzungen betroffen ist, bestätigte sich das Gegenteil: Die untere Extremität (Femur, Tibia, Fibula) wies signifikant mehr Verletzungen auf (20 von 30 Verletzungen). Die Fibula allein machte 10 der 30 Verletzungen aus und wies eine ungewöhnlich hohe Verletzungshäufigkeit auf. Die erzielten Ergebnisse stehen im Einklang mit anderen Traumastudien über das frühe Mittelalter, wobei viele Friedhöfe, die mit den Awaren in Verbindung gebracht werden, eine überraschend niedrige Verletzungshäufigkeit aufweisen, die hauptsächlich durch Unfälle und berufliche Gefahren in der Landwirtschaft und Viehzucht verursacht wurde. Die gut verheilten Verletzungen der Langknochen sind ein Zeichen für die Behandlung und Fürsorge für Menschen, die zumindest vorübergehend nicht in der Lage waren, zu ihrer Gemeinschaft beizutragen. Obwohl die letzten Phasen der Awarenzeit von mehr Unsicherheit und Veränderungen geprägt zu sein schienen, blieb die Bevölkerung von Mödling eine friedliche Gemeinschaft, die sich um ihre Verletzten kümmerte.