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Fracture of the odontoid process in a male individual from the medieval necropolis of Maro (Málaga, Spain)

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ABSTRACT

Traumatic injuries are commonly reported in paleopathology. However, fractures of the odontoid process in past populations are uncommon and therefore such injuries may be easily overlooked. This paper describes alterations of the first and second cervical vertebrae, the atlas and axis, of a male individual of advanced age from the medieval necropolis of Maro (Málaga, Spain). These alterations were observed through macroscopic evaluation and radiological analysis. This individual's skeleton is well-preserved, with degenerative changes present in the appendicular skeleton and the rest of the vertebrae. Our differential diagnosis included aplasia of the dens, bifid dens, dens duplicated, ossiculum terminale persistens, os odontoideum, and odontoid process fractures. We concluded that the most likely condition was a broken odontoid process fused with the anterior arch of the atlas, a pseudarthrosis demonstrating that the individual survived this fracture. This study is one of the first reports of an odontoid process fracture in ancient contexts.

1. Introduction

Traumatic injury, together with degenerative changes, constitutes one of the most common pathologies that affect the skeleton (White et al., 2012). Such injuries may reflect the lifestyle and well-being of individuals and communities (Işcan and Steyn, 2013).

Fractures are commonly reported in ancient skeletal remains, although the study of these injuries can be a difficult task due to poor preservation of skeletal remains (Pinhasi and Mays, 2008). Despite their frequency in archaeological contexts, instances of trauma to the spine are uncommon, and cases where an individual survived fracture of the cervical vertebrae are even rarer (Capasso et al., 1999; Hill et al., 1995; Phillips, 2005).

In paleopathology, only a few of odontoid process fractures have been described. One report details this type of injury in the Ernest Witte site, Texas, US (3000–1500 BCE) in a 35–50-year-old male (Taylor, 2006). Other examples were found in a 40–50-year-old male, belonging to the archaeological excavation of Alamanns, dated chronologically to the 6th-8th century CE (Stammheim, Germany) (Weber et al., 2004), and at the Rincón de Ademuz (17th–18th century CE) (Valencia, Spain) in an individual for whom neither age nor sex was specified (Pulchat-Fortea, 2010).

The purpose of this paper is to describe the alterations found on the first and second vertebrae, the atlas and axis, of an individual excavated from the medieval necropolis of Maro, in Nerja (Málaga, Spain). The abnormal changes result from a fracture of the axis's odontoid process. Our differential diagnosis that includes aplasia of the dens, bifid dens, dens duplicated, ossiculum terminale persistens, os odontoideum, and odontoid process fractures.

2. Material and methods

In 2003, archaeological excavation of a medieval necropolis took place in the locality of Maro, a district in the municipality of Nerja, which is located in the province of Málaga (Spain). This site has been dated chronologically, based on the types of burial, to the end of the 10th century CE – beginning of the 11th century CE (Rodríguez et al., 2004). Overall, the human skeletal remains were well preserved.

The age, sex, and stature of each individual were assessed. Age was estimated using the methods of Brooks and Suchey (1990), Lovejoy et al. (1985), Meindl and Lovejoy (1985), and Todd (1921). Sex was predicted using the method of Phenice (1969), and the discriminative formulae of Alemán et al. (1997) and Viciano et al. (2013). Stature was calculated using the formulae of Mendonça (2000). In non-adults, individuals from birth to 20 years old (Buikstra and Ubelaker, 1994), age was estimated using the methods of Scheuer and Black (2000), and Ubelaker (1978). Sex was estimated using the figures of Schutkowski (1993), and the discriminative formulas of Viciano et al. (2013). The estimation of sex in non-adult individuals is more complex and less precise than in adults, because secondary sexual characteristics have

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not developed. Each individual was examined for the presence or absence of pathological conditions and developmental variants through macroscopic evaluation, differential diagnosis and radiological analysis.

During this excavation, 365 individuals were exhumed. The anthropological study that we conducted of the 365 individuals reflected that 177 (48.5%) were non-adults, 171 (46.8%) adults, and 17 individuals (4.7%) for whom, due to poor preservation, age was impossible to estimate. From the 365 individuals, 144 (39.5%) were identified as male, 185 (50.7%) female, and 36 (9.9%) not estimated.

3. Results

Based on cranial sutures closure, age-related changes of auricular surface, and long bones measurements (Lovejoy et al., 1985; Meindl and Lovejoy, 1985; Alemán et al., 1997), our subject is an older adult male (50–60 years old) His height is estimated to be 163.26 cm +/−6.96, based on Mendonçás formula (2000). Degenerative alterations were noted in the appendicular skeleton and in the vertebrae. The most remarkable changes were found in the two first cervical vertebrae.

On the posterior aspect of the anterior arch of the atlas was an adhered mass, in the position where the odontoid process usually articulates. This mass was the odontoid process that had separated from the axis body and fused to the atlas (Fig. 1A). This odontoid process was irregular and porous. At the base of the odontoid process, a polished and porous facet has formed, which articulates with the axis body (Fig. 1B).

The odontoid process is therefore not attached to the axis. The superior aspect of the axis body shows a flattened surface, with significant porosity and irregular edges (Fig. 2A). The inferior aspect of the axis body has raised ridges, with the formation of osteophytes (Fig. 2B).

The radiograph of the atlas (Fig. 3A) indicates that the odontoid process is fused to the anterior arch. There is a denser area corresponding to the place where the odontoid process has fused. In the radiograph of the axis (Fig. 3B), a fine cortical edge in the superior aspect of the body is observed, which corresponds to the fracture line.

4. Differential diagnosis

For the differential diagnosis, it is necessary to consider various conditions that can lead to anomalies of the axis. These are aplasia of the dens, bifid dens, dens duplicated, ossiculum terminale persistens, os odontoideum, and odontoid process fractures (Akobo et al., 2015; Bajaj et al., 2010; Barrera et al., n.d.; Candan et al., 2014; Glasser and Glasser, 1991; Nune et al., 2015; Rothman and Simeone, 1985). The congenital anomalies that affect the odontoid process are rare, and injuries resulting from these anomalies are usually detected after trauma (Bajaj et al., 2010; Barrera et al., n.d.; Glasser and Glasser, 1991; Rothman and Simeone, 1985). Table 1 shows the characteristics of the main congenital anomalies of the axis.

The presence of an independent odontoid process, showing osseous discontinuity with the axis body, may result from an odontoid process fracture or os odontoideum. Os odontoideum may have a congenital or post-traumatic etiology.

Congenital os odontoideum is often associated with other developmental anomalies, such as occipitalization, hypoplastic atlas, incomplete closure of atlas, basilar invagination, Chiari malformation, skeletal dysplasia, Morquio syndrome, Down syndrome, or Klippel-Feil syndrome (McHugh et al., 2012; Rothman and Simeone, 1985; Sankar et al., 2006). In congenital os odontoideum the edges of the superior aspect of the axis body are flat (O'Brien et al., 2015).

Advocates of post-traumatic os odontoideum suggest that this separation occurs following a fracture in the base of the odontoid process after acute ligament disruption or due to vascular impairment consequent to the trauma (Begum et al., 2014; Candan et al., 2014; Ellis and Kaan, 1993; Galli et al., 2001; Ricciardi et al., 1976). Proponents indicate os odontoideum is an odontoid process fracture in which the dens is separated from the axis body and the injured individual survives (Pathria, 1995; Scheuer and Black, 2000). In an odontoid process fracture the edges of the superior aspect of the axis body are irregular (O'Brien et al., 2015).

In the individual addressed in this paper, macroscopic and radiological evidence of trauma are observed, and there are no developmental anomalies. Therefore, these observations are suggestive of an odontoid process fracture or post-traumatic os odontoideum.

4.1. Fractures of the odontoid process

A fracture is a discontinuity in bone tissue, with or without soft tissue injury (Aufderheide and Rodríguez-Martín, 1998). In general, trauma leaves a mark on the skeleton in the form of a fracture, dislocation, or subperiosteal contusion. After a survived traumatic episode, bone consolidation begins (Aufderheide and Rodríguez-Martín, 1998). This process is divided into three phases (Hoppenfeld and Murthy, 2001; Ortner, 2003):

1. Inflammatory: An increase in vascularization leads to the formation of a hematoma, which is invaded by inflammatory cells that clear necrotic tissue. Radiographically, the fracture line is more visible when the clot forms than at the time of fracture.
2. Repair: The hematoma is invaded by chondroblasts and fibroblasts that form the callus matrix. Initially, a soft callus composed of fibrous tissue and cartilage is formed. Osteoblasts make a hard callus of spongy tissue that increases the stability of the fracture. Radiographically, the fracture line begins to disappear.
3. Remodeling: The woven bone is replaced by laminar bone. The medullary canal is reformed; bone resorption takes place in the convex surfaces, and new bone formation in the concave. Radiographically, the fracture line may not be apparent.

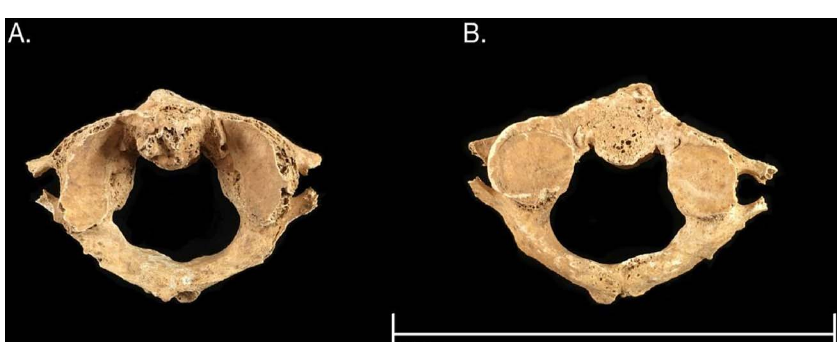

Fig. 1. (A) Atlas with odontoid process fused to the posterior aspect of the anterior arch. Superior view. (B) At the base of the odontoid process fused to the anterior arch of the atlas a joint facet has formed with the axis body. Atlas inferior view.