Hemifacial microsomia (oculo-auriculo-vertebral spectrum) in an individual from the Teramo Sant'Anna archaeological site (7th–12th centuries of the Common Era, Italy)

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RUNNING TITLE: Hemifacial microsomia: a case report

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ABSTRACT

Background: This study is based in an analysis of the skeletal remains of an adult male from the Teramo Sant'Anna archaeological site (7th–12th centuries of the Common Era, Teramo, Italy).

Results and Discussion: The individual shows distinct abnormalities that principally involve asymmetric hypoplasia and dysmorphogenesis of the facial skeleton. The combination of these findings and the absence of abnormalities of the spine strongly suggest diagnosis of the congenital malformation known as hemifacial microsomia. This very heterogeneous syndrome affects primarily aural, ocular, oral and mandibular development. Despite the lack of clinical information and the absence of soft tissue, it was possible to perform a differential diagnosis for this palaeopathological case. Mastication was probably altered considering that the mandible is extremely asymmetric and lacks true condyles. The temporomandibular joints are present, but the right one is hypoplastic and abnormal in shape. There is evidence of bilateral dislocation, and the facial muscles are hypertrophic.

Conclusions: This case represents an important contribution to the palaeopathological literature because this is an uncommon condition that has not been widely documented in ancient skeletal remains.

KEY WORDS: Facial asymmetry; facial dysmorphogenesis; aplasia/hypoplasia of mandibular condyles; condyle dislocation; congenital malformation complex; palaeopathology

1. Introduction

Facial asymmetry is common in humans, which is seen as a disproportionality or imbalance between the right and left sides. Indeed, a mild degree of asymmetry is normal and acceptable in the average face (Chia, Naini & Gill, 2008; Jones & Tier, 2012). However, when the disparity is significant, this can cause both functional and aesthetic problems through a series of factors that can affect the underlying skeletal structure and/or soft tissue. The aetiology includes: (i) congenital disorders that originate prenatally; (ii) acquired disorders that result from injury or disease; and (iii) developmental deformities that arise during growth without any conspicuous aetiology (Cheong & Lo, 2011).

Oculo-auriculo-vertebral spectrum (OAVS) is a congenital malformation complex that is characterised by a wide spectrum of symptoms and phenotypes that can vary in severity from case to case. However, such abnormalities tend to principally involve asymmetric hypoplasia and dysmorphogenesis of the facial skeleton, the external and middle ears, the facial soft tissues, and/or the spine. In 20% of individuals with OAVS, there is marked facial asymmetry, although some degree of asymmetry is evident in 65% of cases (Cohen, Rollnick & Kaye, 1989; Gorlin, Cohen & Hennekam, 2001). In the literature there is considerable discrepancy in the reported frequency of OAVS, ranging from 1 per 5,642 individuals (Grabb, 1965) to 1 per 45,000 individuals (Morrison, Mulholland, Craig & Nevin, 1992).

Hemifacial microsomia (HFM) is one of the more common forms of this OAVS complex, and it primarily affects aural, oral and mandibular development. HFM can vary from mild to severe, and in many cases, involvement is limited to one side of the face, although bilateral involvement can also occur with more severe expression on one side (Gorlin et al., 2001). Goldenhar syndrome is considered as a variant of HFM, and it is characterised additionally by vertebral anomalies and epibulbar dermoids (Gorlin et al., 2001).

Thus, OAVS encompasses both HFM and Goldenhar syndrome. Goldenhar syndrome might also be a more complicated form of OAVS, while HFM might represent a milder form. Thus, an individual with just a small or abnormal ear and no other problems, might be at the very mildest end of this spectrum (Cohen et al., 1989).

Although OAVS is a relatively common modern clinical finding, few cases have been reported in the palaeopathological literature. The published cases have been exclusively based on palaeoepidemiological studies (Castro, Moreno & Aspillaga, 1997), morphological examinations of skeletal remains (Ginestà, Díaz & Ollich, 2013; Nagar & Arensburg, 2000; Panzer, Cohen, Esch, Nerlich & Zink, 2008), or ceramic culture (Pachajoa, Rodríguez &

Isaza, 2010). It appears that the relative lack of cases reported to date might be due to several factors, such as the little attention that has been paid to this condition in recent years.

The purpose of this paper is to describe a probable case of OAVS in an individual recovered from the Teramo Sant'Anna archaeological site (7th-12th centuries of the Common Era (CE); Teramo, Italy). Considering the lack of similar evidence from archaeological skeletal remains worldwide, this case is also extremely valuable to the understanding of the incidence of this type of congenital malformation among past populations.

2. Material and methods

2.1. Archaeological context

In 1980, the *Soprintendenza Archeologica dell'Abruzzo* undertook a series of annual excavation campaigns under Sant'Anna Square, in the historic centre of Teramo (Fig. 1). During the period from 1980 to the summer of 1990, the remains of a Medieval Cathedral were discovered, which according to historic documents existed between the centuries 6th-14th CE, next to a Roman *domus*. Dozens of graves were also found, which contained mainly well-preserved skeletal remains. There were also hundreds of human and animal bones distributed sporadically at various stratigraphic levels throughout the excavated area (Capasso, Di Muzio, Di Tota & Spoletini, 1990). The Medieval necropolis extended all around the perimeter of the Cathedral, so that part of it also impinged on the ruins of the ancient Roman *domus*. Radiocarbon dating demonstrated an outward spreading use of the necropolis with respect to the perimeter of the Cathedral (Calderoni & Petrone, 1990); indeed, the graves closest to the perimeter walls of the Cathedral are the oldest (600-685 AD), compared to the more distant ones, located on the Roman *domus* (1000-1160 AD) (Capasso et al., 1990).

2.2. Preservation and completeness

The skeletal remains considered here were classified as individual T.D-I.31. The cranium was almost complete (i.e., missing only a fragment of the occipital bone), with a well-preserved mandible. The upper body elements were optimally preserved despite the fragmentation of the ribs and left scapula. The lower body elements were also well preserved. The only missing bones were the majority of the right and left tarsals, carpals, metatarsals,

metacarpals and phalanges. The skeletal remains are housed at the University Museum of Chieti ('G. d'Annunzio' University of Chieti–Pescara, Chieti, Italy).

2.3. Examination methods

The sex of individual T.D-I.31 was determined by applying standard osteological methods for the cranial and pelvic features, based on descriptive and metric criteria (Bruzek, 2002; Ferembach, Schwidetzky & Stloukal, 1980; Murail, Bruzek, Houet & Cunha, 2005; Viciano, D'Anastasio & Capasso, 2015b). As the cranium showed morphological abnormalities, the pelvic features were the main indicators of the sex. According to these criteria, the individual T.D-I.31 was sexed as male. The age at death of individual T.D-I.31 was estimated at 40 years to 45 years and was based on the appearance of the pubic symphyseal surface (Katz & Suchey, 1986) and the ilium auricular surface (Buckberry & Chamberlain, 2002), and according to the sternal ends of the ribs (Işcan, Loth & Wright, 1984).

The dental characteristics were analysed using dentistry and dental anthropological criteria, particularly in terms of oral disease. Tooth wear was scored using the eight-stage method of Smith (1984). The presence or absence of calculus deposits was scored, as well as their severity, following the Brothwell criteria (Brothwell, 1981). The tooth notation system used was that proposed by the World Dental Federation (*Fédération Dentaire Internationale*; FDI) (FDI, 1971).

The skeletal remains were inspected macroscopically and radiographically for any evidence of pathological conditions. X-ray analysis of the skull and mandible was carried out at the Villa Serena Hospital (Pescara, Italy) using a digital radiography system. The method of Rando and Waldron (2012) was used to evaluate the signs for osteoarthritis of the temporomandibular joint (TMJ). Any signs of pathological conditions were recorded and described, and the differential diagnosis was defined.

3. Results

3.1. Description of the pathological findings

The postcranial skeleton did not show any evidence of pathological conditions, so the analysis for this study focused on the cranium. Only signs of intervertebral disc disease and Schmörl nodes (Waldron, 2009) were observed in the vertebrae. Fig. 2 shows the different

views of the cranium of individual T.D-I.31 from the Teramo Sant'Anna archaeological site (7th-12th CE, Teramo, Italy), illustrating the evident hypoplasia and dysmorphogenesis of the facial skeleton.

3.1.1. Skull

In the anterior view, the nasal bones had a normal hour-glass shape, but the left one was slightly hypoplastic (i.e., it was narrower near the nasofrontal suture), which resulted in a deviation of the internasal suture to the left, and septum displacement. The piriform aperture also showed a slightly asymmetric shape (Fig. 3).

In the inferior view, both palatine processes of the maxilla had a normal shape, although the median palatine suture was deviated to the left with reference to the sagittal plane (Fig. 4). A *torus palatinus* at the middle of the hard palate was also observed. This bony prominence had a lobular shape and it was asymmetric in the palate: the torus in the right palatine process was barely discernible, but in the left one, it was more prominent. Both the mastoid processes and the external auricular meatus had normal shapes, but their positions in the base of the skull were asymmetric regarding the coronal plane (Fig. 4). The glenoid fossa was not developed on the right side, and it was underdeveloped on the left side (Fig. 5A). The right articular eminence showed a shallow and smooth surface, with no signs of osteoarthritic changes. The left articular surface consisted of a large, deep and circular depression measuring approximately 1.9 cm in diameter, which showed considerable porosity and lipping, with an eburnated surface in the deepest part of the articulation ('florid expression' degree according to Rando & Waldron, 2012) (Fig. 5B). These are indicative signs of osteoarthritis of the TMJ (Rando & Waldron, 2012).

Radiographic images of the skull (Fig. 6) showed the asymmetry of the frontal sinuses and an evident *calcar occipitis*. The X-rays did not reveal trauma or other pathological signs.

3.1.2. Mandible

When the mandible was articulated with the skull, it showed a deviation to the right side relative to the midline, which induced malocclusion (Fig. 2). The mandible was extremely asymmetric and lacked true condyles (Fig. 7). On the right ramus (Fig. 8A), the entire supero-posterior part was missing, which showed a smooth surface with no sign of osteoarthritic changes. On the left ramus (Fig. 8B), a strongly deformed condyle was observed, which was

folded postero-medially and slightly welded perpendicular to the mandibular ramus. There were erosive changes (pitting) and osteophytic lipping at the articular surface margins, with signs of eburnation in the superior part of the articulation ('florid expression' degree according to Rando & Waldron, 2012), suggesting the diagnosis of osteoarthritis of the TMJ. The coronoid processes were hyperplastic (i.e., unusually wide, thick, arch-shaped), which extended above the zygomatic arch. The vertical elongation of the coronoid processes resulted from hyperstimulation of the temporal muscle, the imprints of which in the areas of insertion were marked. Both mandibular notches showed abnormal shapes due to the absence of true condyles of the mandible and hyperplasia of the coronoid processes. The mandibular foramina faced posteriorly, surrounded by thick bony walls. These were rounded, and conical in shape. Below the foramina, a series of transverse ridges were apparent. These markings of the medial pterygoid muscle started at the gonion and increased in size and roughness as they ascended both rami. The upper part of the muscle attachment area had a slight tubercle that corresponded to hypertrophy of the superior-most fibres (Fig. 8). Both gonion areas were square in shape, slightly projecting laterally. On the lateral aspect of the rami, the masseter muscle insertion showed a prominence that ascended vertically from the gonion. On the right side (Figs. 7 and 8), the antegonial notch (i.e., the junction between the ramus and the body of the mandible, near the anterior margin of the masseter muscle attachment) had a strongly concave inferior border. The body of the mandible had enlarged mental foramina, and their position in the anterior view was asymmetric. Mental spines were well developed.

Radiographic examination (Fig. 9) did not reveal signs of fractures in the condyles or the antegonial notches, thus excluding a traumatic event as the origin of the abnormalities.

3.1.3. Dentition

Only seven teeth were missing (teeth 31, 37 and 41 were lost postmortem; teeth 18, 28, 38 and 48 were agenetic). Teeth 11, 13, 23, 32, 33, 35, 36 and 42 were present, but had fractured crowns at the level of the cementoenamel junction; thus, part of the roots were inserted in the alveolus and the crowns were isolated. The rest of the teeth were inserted in their respective alveoli (Figs. 4 and 7). All of the teeth showed slight/moderate levels of deposition of supragingival calculus deposits for the vestibular and/or lingual surfaces (Figs. 3 and 10), without apparent signs of deposits on their incisal/occlusal surface. The anterior teeth showed slight incisal attrition (i.e., moderate-to-full cusp removal, some punctuated dentine exposure), whereas the posterior teeth were more worn, with moderate areas of exposed

dentine in the occlusal surface. The maxillary and mandibular posterior teeth also showed signs of periodontal disease (Fig. 10). There were no signs of hypoplastic defects, and only tooth 36 had a small carious cavity in the mesial interproximal surface that clearly penetrated the dentine.

4. Discussion

Asymmetry of the craniofacial skeleton can be caused by many factors, such as by postmortem distortion caused by postdepositional earth pressure, or during post-excavation preparation or treatment of the specimen, and by antemortem factors that include pathologies and artificial deformation (i.e., deliberate, accidental) (Kaifu et al., 2009). A certain degree of non-pathological asymmetry in the body is common in healthy individuals (Cheong & Lo, 2011); nevertheless, individual T.D-I.31 showed craniofacial asymmetries that cannot be explained by postmortem deformation.

It has been demonstrated that facial asymmetry due to mandibular asymmetry is a relatively common problem in patients with disorders of the TMJ (Inui, Fushima & Sato, 1999). Facial asymmetry can be seen to arise from fractures of the oral cavity (De Luca et al., 2013; Viciano, López-Lázaro, Cesana, D'Anastasio & Capasso, 2012; Viciano, D'Anastasio & Capasso, 2015a; Yamashiro, Okada & Takada, 1998), pathological conditions, such as tumours and cysts (Ensari, Gur, Ozturk, Osma & Selcuk, 2016; Pereira-Santos, De Melo, Brêda, Sonoda & Hochuli-Vieira, 2013), and inflammatory conditions, such as juvenile rheumatoid arthritis (Alexandersen, Szlachetko & Wiercinska, 1979; Demant et al., 2011; Larheim, Dale & Tveito, 1981). The form and outline of the skull and mandible in individual T.D-I.31 did not indicate either pathological or inflammatory conditions.

Facial asymmetry can also be seen in connection with different syndromes of the head and neck (Gorlin et al., 2001), which can result in deviation of the midline, and malocclusion as a consequence of abnormalities of the TMJ due to any alteration in size and/or shape of the mandibular condyle. Disturbances in the development of the mandibular condyle can result in aplasia, hypoplasia, hyperplasia or bifidity of the mandibular condyle and its associated soft tissues (Kaneyama, Segami & Hatta, 2008). Hypoplasia or aplasia of the mandibular condyle indicates underdevelopment or non-development associated mainly with various craniofacial abnormalities. Several studies have suggested a distinction between congenital and acquired hypoplasia/aplasia (Gorlin et al., 2001; Rabey, 1977; Tank, Wright & Iizuka, 1998). The congenital form is characterised by unilateral or bilateral underdevelopment of the mandibular

condyle, and it usually occurs as part of some systemic condition that originates in the first and second branchial arches. For the acquired (secondary) form, normal development of the condyles proceeds until the lytic event occurs. This can be caused by local factors (e.g., trauma, infection of the mandibular bone or middle ear, irradiation) or by systemic factors (e.g., toxic agents, rheumatoid arthritis, mucopolysaccharidosis) (Tank et al., 1998). In individual T.D-I.31, the macroscopic and radiological data of the mandible did not provide any information related to fractures or infectious diseases of the condyles. Therefore, the abnormalities of the mandibular condyles and their related structures appeared to correspond to a congenital form characterised by underdevelopment (hypoplasia) of the left mandibular condyle and non-development (aplasia) of the right mandibular condyle and the related glenoid fossa.

Aplasia of the mandibular condyle without any other facial malformations is extremely rare, but it has been reported previously in several studies (Canger & Çelenk, 2012; Krogstad, 1997; Prowler & Glassman, 1954; Rajarathnam, David & Kumar, 2016; Shivhare, Shankarnarayan, Usha, Kumar & Sowbhagya, 2013; Shivhare, Lata, Balaji & Gupta, 2015). Aplasia of the mandibular condyle is frequently a facial manifestation of a variety of congenital syndromes (Gorlin et al., 2001; Nagar & Arensburg, 2000; Panzer et al., 2008), such as OAVS.

4.1. Differential diagnosis

In clinical medicine, diagnosis of OAVS is based on the combination of marked facial asymmetry and characteristic facial phenotypes, which can include ear anomalies, such as microtia and preauricular tags, and eye anomalies, such as microphthalmia, epibulbar dermoids and colobomas. Other characteristic features include anomalies of the facial skeletal support, such as aplasia or hypoplasia of the mandibular ramus and condyle, and size reduction and flattening of the maxillary, temporal and malar bones. Occasionally, other anomalies related to the central nervous system, trachea, lungs, heart, kidneys and gastrointestinal tract can be observed (Cohen et al., 1989; Gorlin et al., 2001).

In palaeopathological studies, due to the lack of soft tissues for any clinical examination, only the macroscopic and radiological analyses of the cranium and postcranial skeleton can be considered in differential diagnosis, to exclude several chromosome disorders and syndromes with overlapping features with OAVS. On the one hand, these can include syndromes with hemifacial or facial microsomia, such as Parry-Romberg syndrome, Treacher-Collins

syndrome, maxillofacial dysostosis, Nager acrofacial dysostosis, and postaxial acrofacial dysostosis, and on the other hand, they can include syndromes with congenital ear anomalies, such as Townes-Brocks syndrome, brachio-oto-renal syndrome, and the collective conditions of vertebral anomalies, ventricular septal defects, anal atresia, tracheoesophageal fistulas with oesophageal atresia, and radial and renal dysplasia known as VATER, coloboma, heart disease, atresia choanae, retarded growth and development, genital anomalies, ear anomalies and/or hearing loss known as CHARGE, and Müllerian duct aplasia, renal aplasia, cervicothoracic somite vertebral dysplasia known as MURCS association.

Parry-Romberg syndrome is also known as progressive hemifacial atrophy, and this consists of slowly progressive unilateral facial atrophy that affects the skin and underlying muscles, and sometimes extends to cartilaginous and bone structures. This syndrome is associated with cranio-maxillofacial and orthodontic abnormalities, such as deviation of the mouth and nose towards the affected side, deficiencies of the soft and hard palates in all dimensions, shortness and deficiency of the mandibular body and ramus, delayed tooth eruption and formation, abnormal root morphology, and in rare cases, root resorption (Al-Aizari, Azzeghaiby, Al-Shamiri, Darwish & Tarakji, 2012; El-Kehdy, Abbas & Rubeiz, 2012; Gorlin et al., 2001).

Treacher-Collins syndrome is also known as mandibulofacial dysostosis, and this is a disorder that is characterised by a particular facial appearance secondary to hypoplastic supraorbital rims and zygomata, the latter being totally absent, or more often, symmetrically underdeveloped, with non-fusion of the zygomatic arches. Here, the zygomatic process of the frontal bone is hypoplastic, as are the lateral pterygoid plates and muscles. The mandibular condyle and coronoid process are also severely hypoplastic, flat, or even aplastic. The angle is more obtuse than normal, and the mandibular ramus is deficient. Cleft palate is occasionally found (Chang & Steinbacher, 2012; Gorlin et al., 2001; Trainor, Dixon & Dixon, 2009).

Maxillofacial dysostosis consists of bilateral hypoplasia of the malar bones, downward-slanting palpebral fissures without colobomas, maxillary hypoplasia, open bite, and relative mandibular prognathism (Escobar, Eastman, Weaver & Melnick, 1977; Gorlin et al., 2001).

Nager acrofacial dysostosis is a mandibulofacial dysostosis that is associated with radial effects. Hypoplasia of the zygomata, maxilla and mandible are an almost constant features here. Limited mandibular movement secondary to functional ankyloses of the TMJs has also been noted. Abnormalities of the palate are frequent, and include cleft palate and highly arched palate. Dental anomalies include enamel hypoplasia and oligodontia. Facial asymmetry is rare. Other common features of the postcranial skeleton are symmetric thumb

hypoplasia or aplasia, triphalangeal thumb, double thumb, syndactyly between thumb and index finger, radial hypoplasia or aplasia, synostosis of carpal bones, hypoplasia of thenar eminence, campodactily, and clinodactily (Gorlin et al., 2001; McDonald & Gorski, 1993).

Postaxial acrofacial dysostosis is a condition that is characterised by malar hypoplasia and micrognathia, as constant findings. Almost all individuals have bilateral hypoplastic or absent thumbs, and the radius and ulna can be fused, or there might be absence or hypoplasia of the radius and/or one or more metacarpals. Syndactyly is occasionally noted, cleft palate is more frequent, and the mandible is more severely retarded in growth than in Treacher-Collins syndrome. Supernumerary vertebrae, vertebral and sternal segmentation anomalies, cervical ribs, and pectus excavatum have also been noted (Gorlin et al., 2001).

The characteristic features of OAVS are distinguishable from these syndromes with hemifacial or facial microsomia (i.e., Parry-Romberg syndrome, Treacher-Collins syndrome, maxillofacial dysostosis, Nager acrofacial dysostosis, and postaxial acrofacial dysostosis), because facial involvement in OAVS is usually asymmetric, with one side of the face thus more severely involved (Gorlin et al., 2001).

On the other hand, there are other syndromes where the symptoms and phenotypic facial features can overlap with the OAVS (i.e., Townes-Brocks syndrome, brachio-oto-renal syndrome, VATER, CHARGE, and MURCS association). However, in contrast to OAVS, in these other disorders facial asymmetry or hemifacial microsomia and other related skeletal malformations like palate abnormalities and malformed middle or inner ear are not typical features, as these have only been described as components that are present towards the severe end of the spectrum (Chen et al., 1995; Gorlin et al., 2001; Smith, 2015).

Although it was not possible to perform an analysis of the pathological soft tissue abnormalities to confirm the aetiology, it was clear that the pathological features described, such as asymmetric hypoplasia and dysmorphogenesis of the facial skeleton, are typical of OAVS. With the involvement more limited to one side and with no abnormalities of the spine, it is more probable that individual T.D-I.31 was affected by a mild version of OAVS, such as HFM.

HFM is often classified based on the degree of TMJ dysmorphology (Mulliken & Kaban, 1987). Pruzansky (1969) reported a grading system of progressive mandibular deficiency: grade I, minimal hypoplasia of the mandible; grade II, functioning but deformed TMJ with anteriorly and medially displaced condyle; and grade III, absence of the ramus and glenoid fossa. This classification was later modified by Kaban, Padwa and Mulliken (1998), who added a description of the TMJ and deformity, which enables a more precise classification.

They established the following classification: type I, all mandibular and TMJ components are present and normal in shape, but are hypoplastic to a variable degree; type IIa, the mandibular ramus, condyle, and TMJ are present, but hypoplastic and abnormal in shape; type IIb, the mandibular ramus is hypoplastic and markedly abnormal in form and location, with it medial and anterior, and with no articulation with the temporal bone; and type III, the mandibular ramus, condyle and TMJ are missing and the lateral pterygoid muscle and temporalis, if present, are not attached to the mandibular remnant. Therefore, the short and abnormally shaped right mandibular ramus observed in individual T.D-I.31, accompanied by aplasia of the condyle and the TMJ displaced inferiorly, medially and anteriorly, can be defined as a 'type IIb'.

4.2. Functional implications

In the development of vertebrate animals, the 'functional matrix' hypothesis is a phenomenological description of bone growth. It postulates that the origin, development and maintenance of all of the skeletal units are secondary, compensatory and mechanically obligatory responses to temporally and operationally prior demands of related functional matrices. That is, that the mass and shape of bones are dependent on the related soft tissues in which the bones reside (Moss, 1960). Several studies have been reported where defects of both muscles and bone in patients with craniofacial anomalies are described (Converse, Coccaro, Becker & Wood-Smith, 1973; Figueroa & Pruzansky, 1982; Heude, Rivals, Couly & Levi, 2011; Huisinga-Fischer, Vaandrager, Prahl-Andersen & van Ginkel, 2004; Marsh, Baca & Vannier, 1989; Mulliken & Kaban, 1987; Nakata et al., 1995; Vargervik & Miller, 1984). These studies have emphasised the direct relationships between alterations in the neuromuscular status of the muscles of mastication and the mandibular dysmorphology in patients with HFM, to conclude that bony malformations are clearly associated with underdevelopment (i.e. hypoplasia) of the different muscles of mastication, such as the masseter, the temporalis, and the medial and lateral pterygoid. In the present case study, the observed hypertrophy of the masticatory muscles did not fall into the generally accepted association of underdevelopment of the temporal, masseter and pterygoid muscles in HFM patients. However, an unusual case of HFM with overgrowth of the facial muscles was reported by Delantoni, Levi and Kondylidou (2009). They concluded that their case might represent a previously unreported characteristic associated with this syndrome, or it might be an unusual finding in a single case of HFM, as could well be the case in the present study.

On the other hand, aplasia/hypoplasia of the mandibular condyles can lead to chin deviation, which causes malocclusion, and consequently functional and masticatory disorders. According to Klein and Howaldt (1995) and Ware (1980), two characteristics can prevent occlusion: an extremely short mandibular body, and the hypoplasia/aplasia of the condyles causing retrusion of the mandible. In individual T.D-I.31, the pattern and extent of dental attrition indicate occlusion (i.e., the mandible was functional). Occlusion was probably achieved due to the displacement of the TMJ antero-inferiorly, a feature characteristic of HFM (Gorlin et al., 2001). Due to the activity of the elevator muscles attached to the ascending rami, without a condylar head on which to rotate due to the abnormalities of the mandibular condyles, the normal upward and forward pull of the masseter and internal pterygoid muscles on the mandible caused an anterior and superior displacement of both rami (Çil, Bozkurt & Bozkurt, 2014; De Luca et al., 2013; Dimitroulis, 1997). This situation led to bilateral dislocation of the mandible, with osteoarthritic alteration of the left articular eminence. Considering the joint disposition and the hypertrophy of the facial muscles, mastication was probably altered. The dental attrition pattern suggested overstress on the posterior teeth compared to the anterior teeth. This wear pattern is common when the vertical height of the mandibular ramus is reduced (Bell, 1979) and the last molar teeth act as a fulcrum by which the mandible rotates, collapsing posteriorly and opening anteriorly; the result is an anterior open bite (Kurt, Öztaş, Gençel, Taşan & Öztaş, 2011). As is evident from the large opening of the mandibular foramina and their disposition facing posteriorly, the axis of the mandible rotation was changed, with the foramina no longer being the pivot point of mandibular movement.

5. Conclusions

Individual T.D-I.31 recovered from the Teramo Sant'Anna archaeological site (7th-12th CE, Teramo, Italy) showed evident hypoplasia and dysmorphogenesis of the facial skeleton. With the involvement limited to one side and with no abnormalities of the spine, it is most probable that individual T.D-I.31 was affected by a mild version of OAVS, such as HFM. Although it was not possible to perform an analysis of the pathological soft tissue to confirm this aetiology, the skeletal features are compatible with this congenital malformation syndrome. These malformations appear to have affected the masticatory functions during the life of the individual. Considering the lack of similar evidence on archaeological skeletal

remains worldwide, this case is extremely valuable to the understanding of the incidence of this type of congenital malformation among past populations.

Conflict of interest

All authors declare no conflict of interest.

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Fig. 1. Location of Teramo, in the region of Abruzzo, Italy.

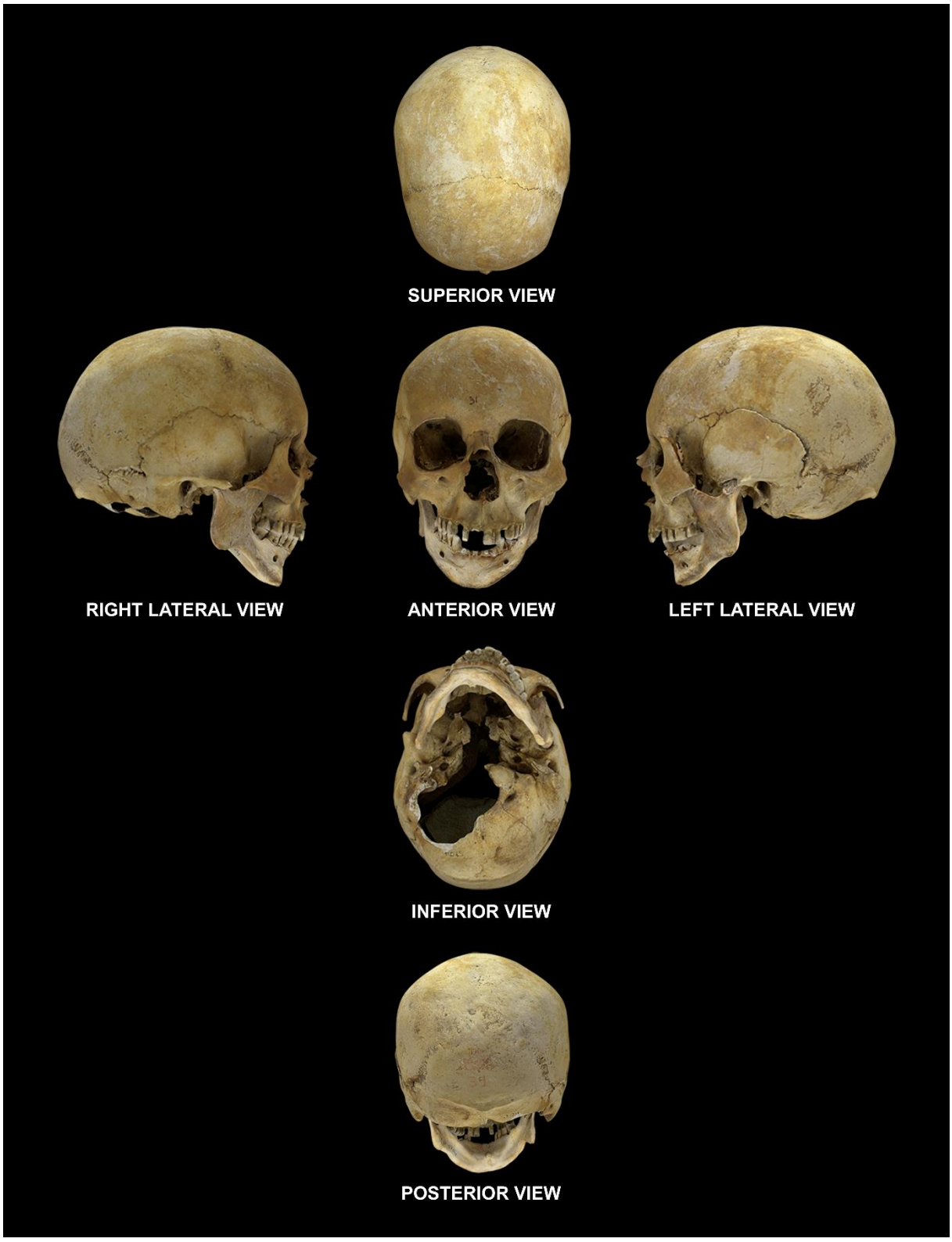

Fig. 2. Different views of the cranium of individual T.D-I.31 from the Teramo Sant'Anna archaeological site (7th-12th CE, Teramo, Italy). Evident hypoplasia and dysmorphogenesis of the facial skeleton can be seen.

Fig. 3. Detail of the nasal bones of individual T.D-I.31, where the left one is slightly hypoplastic, which resulted in a deviation of the internasal suture to the left. The piriform aperture also shows a slight asymmetric shape.

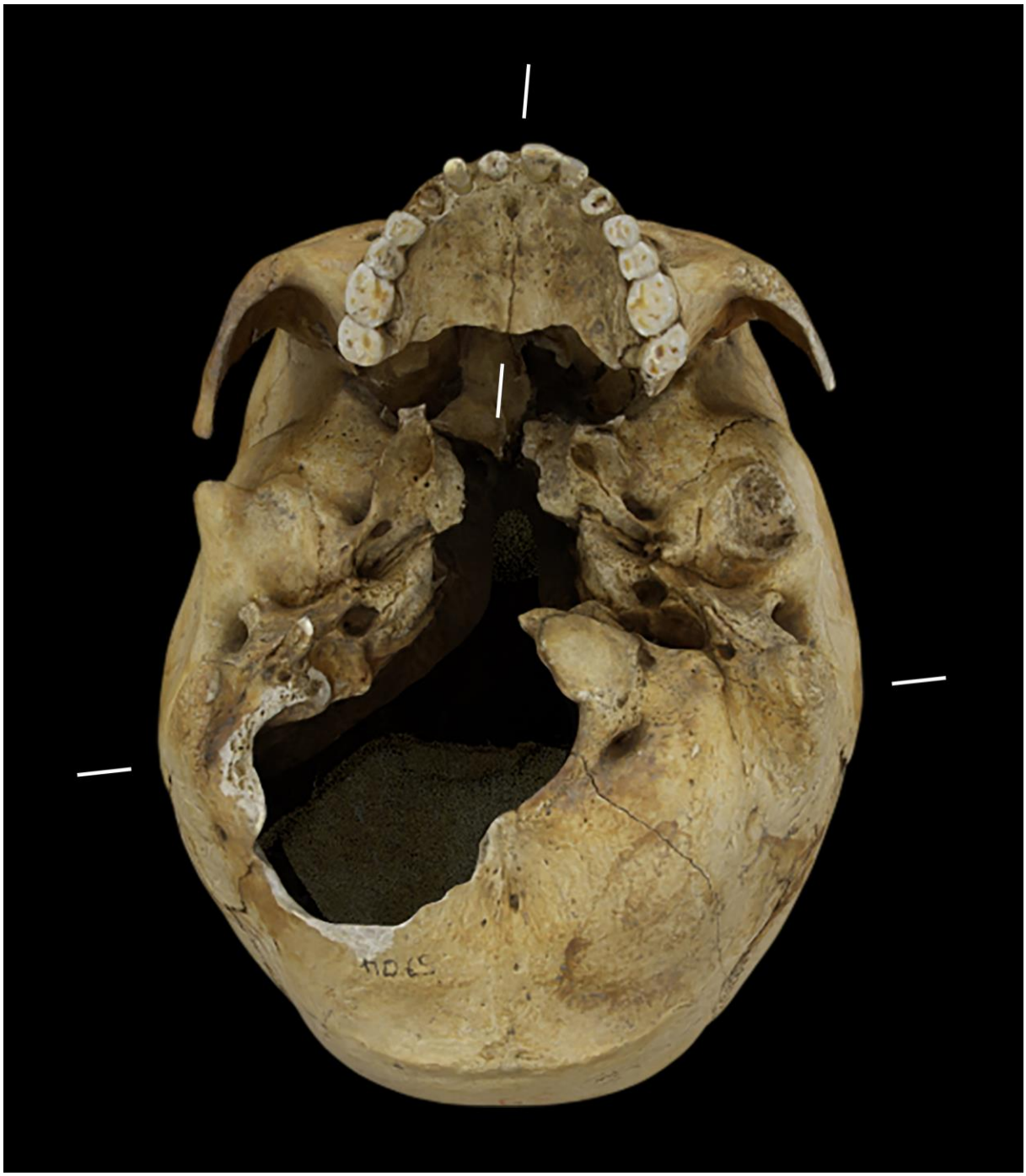

Fig. 4. Inferior view of the skull of individual T.D-I.31. The image illustrates the deviation of the median palatine suture to the left with respect to the sagittal plane, and the asymmetric position of both mastoid processes and the external auricular meatus with respect to the coronal plane. Lines passing through the most lateral points of the right and left parietal bones, and running along the midline of the hard palate, are indicated.

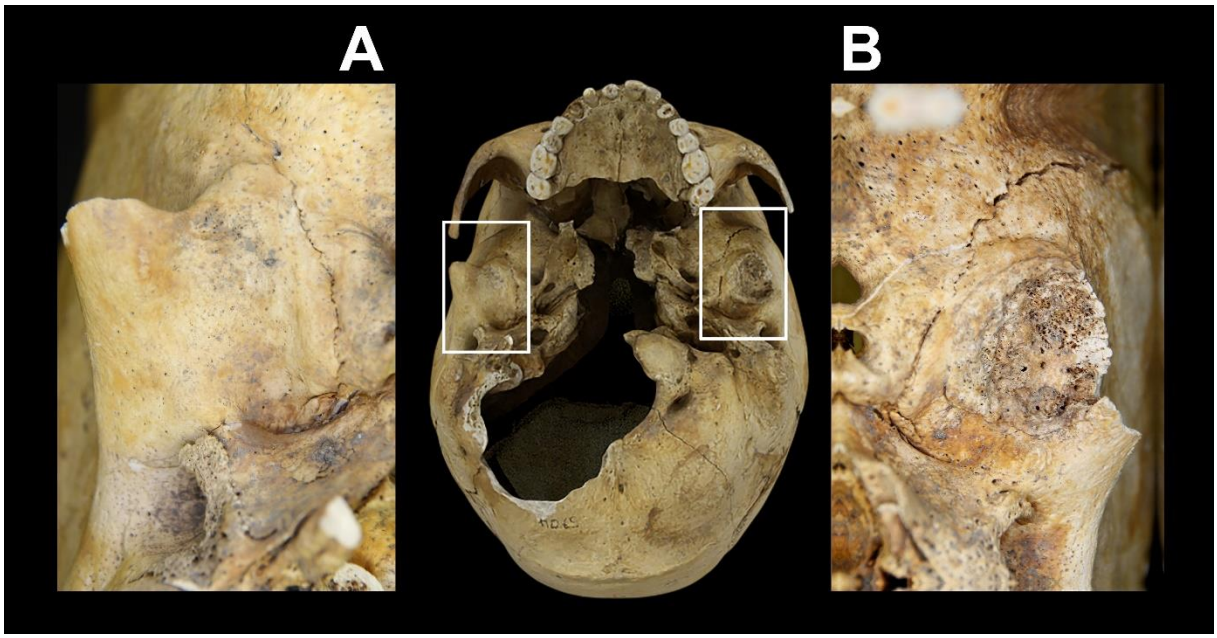

Fig. 5. Inferior view of the skull of individual T.D-I.31, showing non-development of the right glenoid fossa (A) and underdevelopment of the left glenoid fossa (B). The right articular eminence (A) shows no signs of osteoarthritic changes. The left articular surface (B) shows considerable lipping and porosity, with an eburnated surface in the deepest part of the articulation.

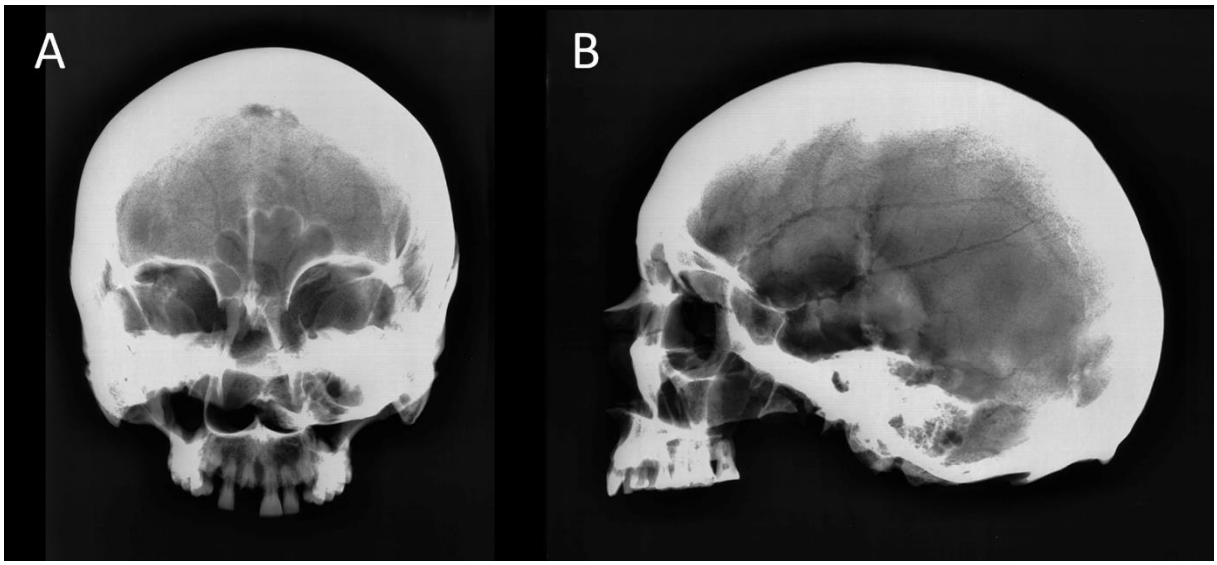

Fig. 6. Antero-posterior (A) and latero-lateral (B) radiographic images of the skull of individual T.D-I.31 from the Teramo Sant'Anna archaeological site (7th-12th CE, Teramo, Italy).

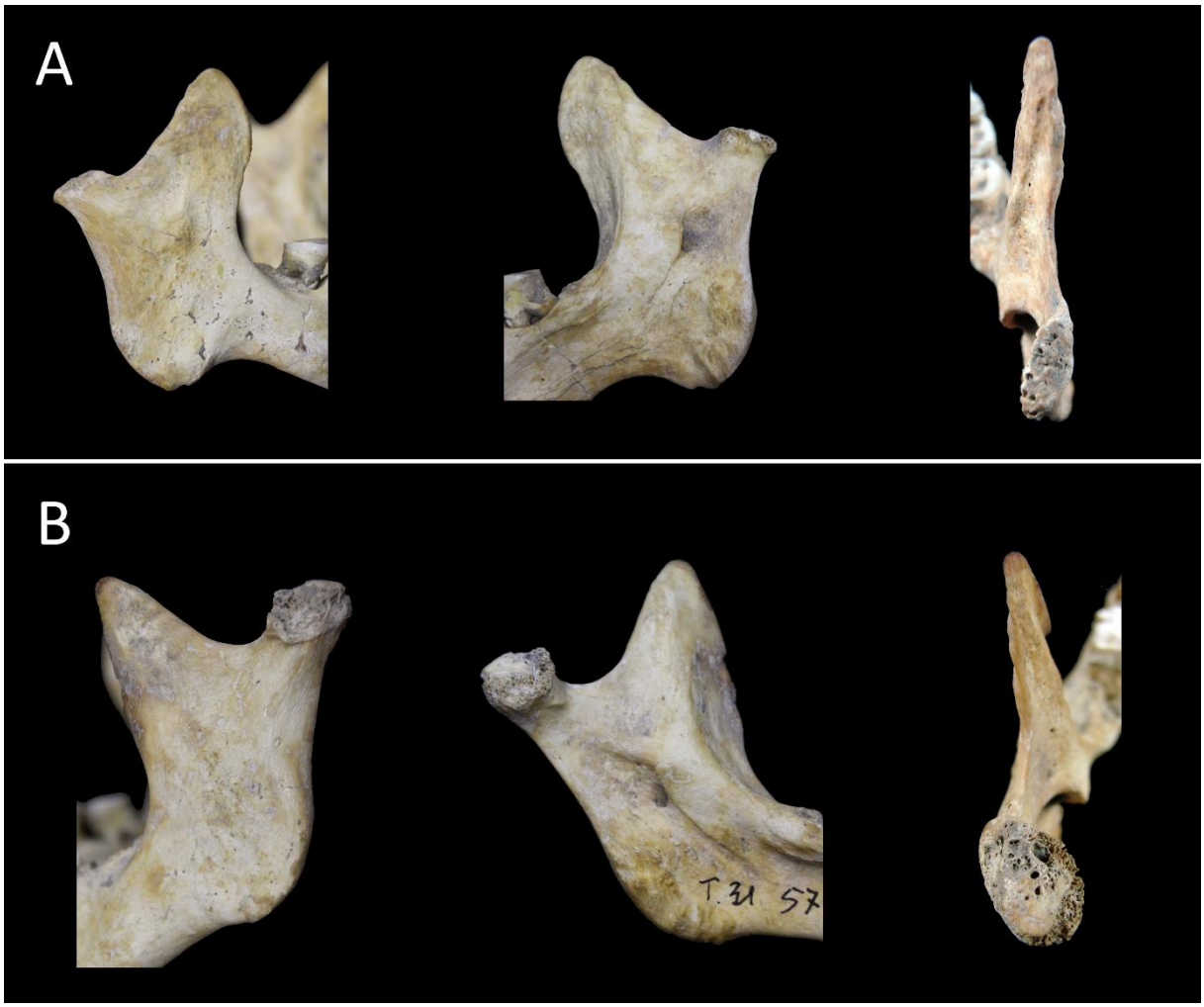

Fig. 7. Different views of the mandible of individual T.D-I.31, showing the fractured crowns in the superior view of the mandible corresponding to mandibular teeth 32, 33, 35, 36 and 42.

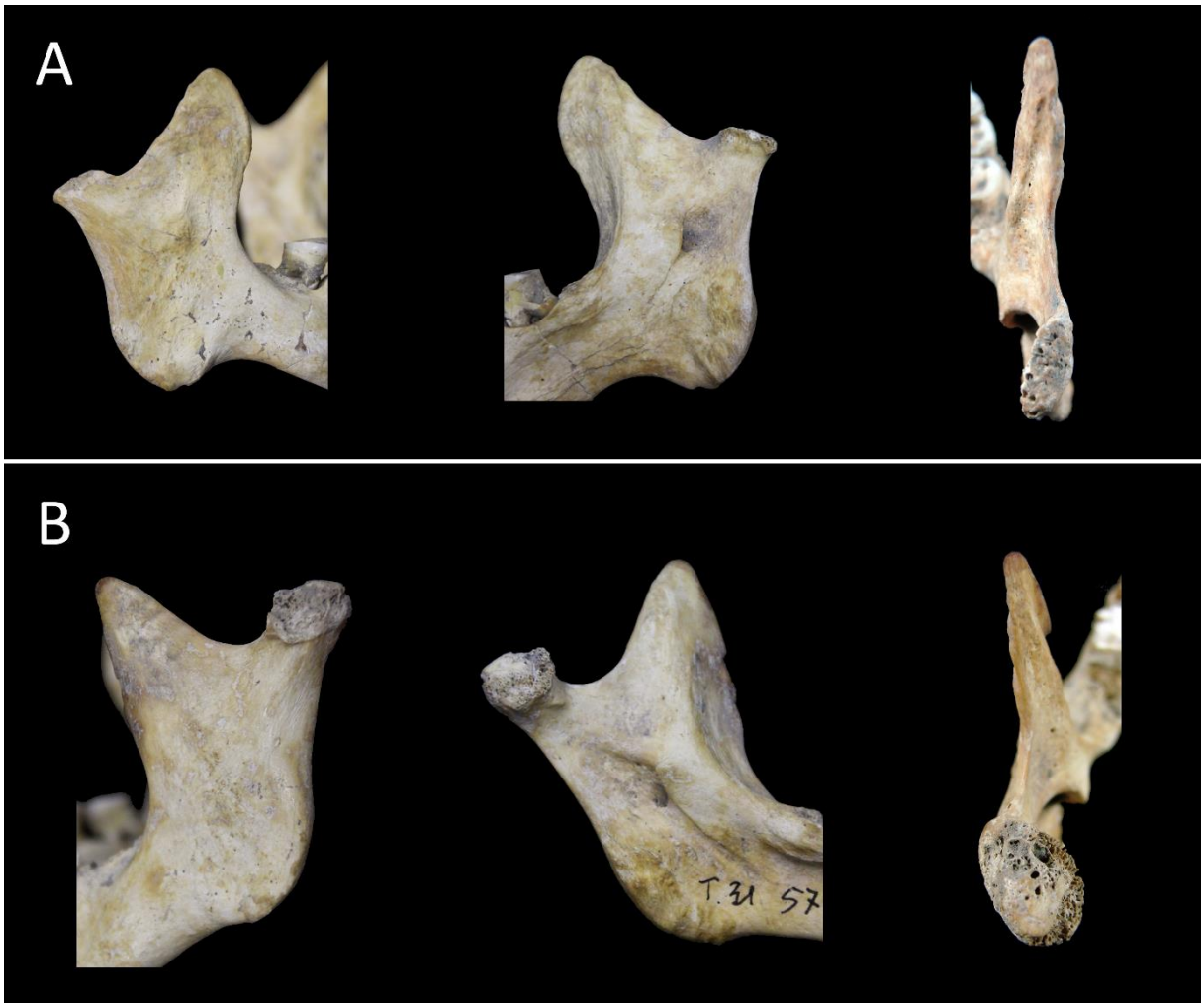

Fig. 8. Abnormal morphology of the condyles of individual T.D-I.31. Underdevelopment (hypoplasia) of the left mandibular condyle and the non-development (aplasia) of the right one can be seen, along with hyperplasia of both of the coronoid processes, and hypertrophy of the different muscles for mastication, including the masseter, temporalis, and medial and lateral pterygoid. (A) Lateral, medial and superior views of the right mandibular ramus. (B) Lateral, medial and superior views of the left mandibular ramus.

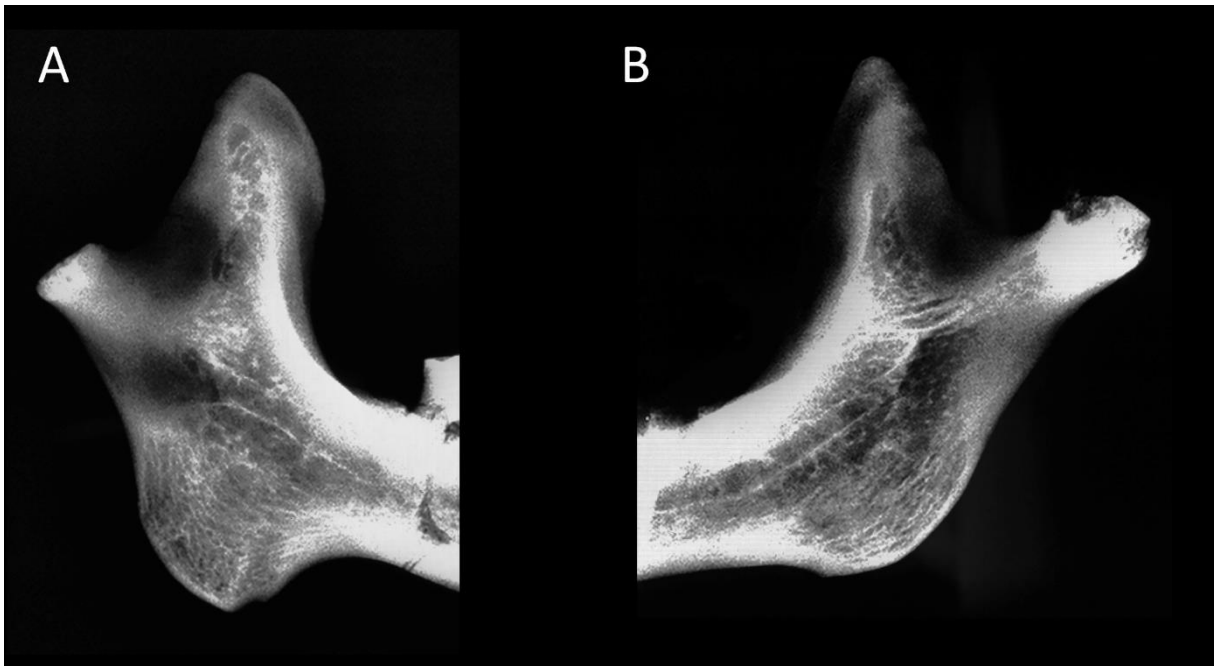

Fig. 9. Radiographic images of the right (A) and left (B) mandibular ascending rami of individual T.D-I.31, showing no evidence of trauma or other diseases.

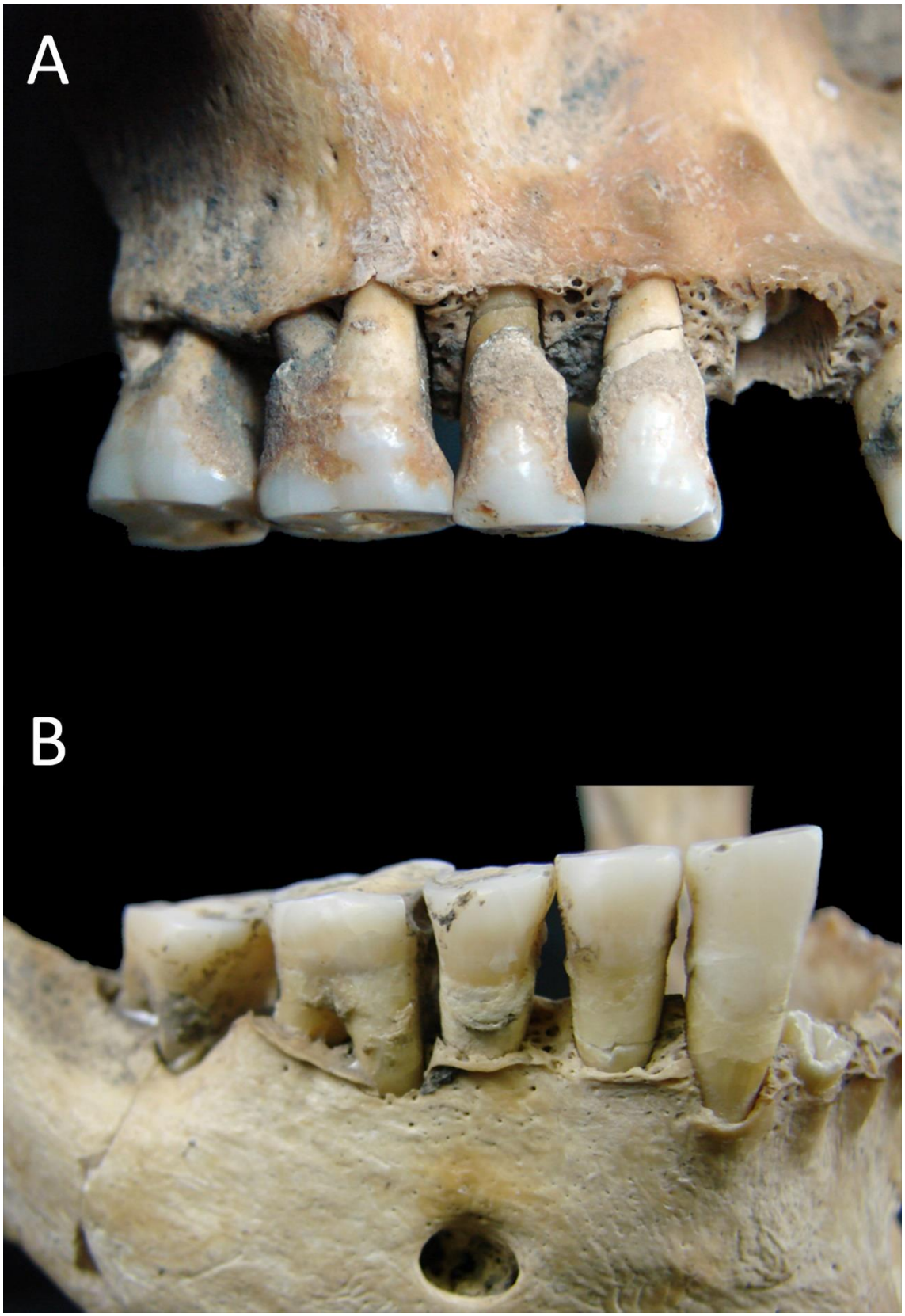

Fig. 10. Maxillary (A) and mandibular (B) posterior teeth (maxilla: teeth 14, 15, 16. 17; mandible: teeth 43, 44, 45, 46, 47) of individual T.D-I.31, showing moderate deposit of calculus for their vestibular surface, and signs of periodontal disease.