



ARTICLE

## Orofacial dysfunction: analysing biomechanics in an individual from the AD 15<sup>th</sup> -17<sup>th</sup> centuries collection of slaves from Lagos (Portugal)

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### ABSTRACT

The aim of this study is to discuss the functional implications of the mandibular and dental asymmetries of an adult male individual from the Lagos's sample of African slaves (AD 15<sup>th</sup>-17<sup>th</sup> centuries, Portugal). The mandible is asymmetrical both morphologically and metrically. A more marked gonial eversion is observed in the left side. The contours of the mandibular lower border are different, being the right almost straight, and the left exhibiting an antegonial notch. The posterior ramus flexure is more pronounced in the left side. A small bone growth is visible only in the left coronoid process. Mandibular measurements are greater in the left side. The greatest disparities between the two sides are found in the projective height of the ramus followed by the coronoid height, where the differences reach 12.8% and 9.7%, respectively. The permanent upper right canine is palatally deviated and, presents a crossbite in occlusion. Posterior teeth (upper and lower) from the left side are more worn. The asymmetrical bony features would have impaired the

function of the craniofacial complex, namely through a muscular, ligamentar and articular overload. Moreover, the crossbite could have reinforced this malfunction. The altered pattern of mastication probably explains the recorded asymmetrical tooth wear.

*Keywords* Mandibular asymmetries; Tooth malposition; Masticatory pattern; Dental wear.

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## RESUMO

O objetivo deste estudo é discutir as implicações funcionais das assimetrias mandibulares e dentárias de um indivíduo masculino adulto da amostra de escravos africanos de Lagos (séculos XV-XVII d.C., Portugal). A mandíbula exhibe assimetria morfológica e métrica. É observada uma eversão gonial mais marcada no lado esquerdo. Os contornos da borda inferior mandibular são diferentes, sendo o direito quase reto, e o esquerdo exibindo um entalhe antegonial mais profundo. A flexão do ramo posterior apresenta-se mais pronunciada no lado esquerdo. Um pequeno crescimento ósseo é visível apenas no processo coronoide esquerdo. As medidas mandibulares são superiores no lado esquerdo. A maior disparidade entre os dois lados é encontrada na altura do ramo mandibular seguido da altura coronoide, onde as diferenças atingem 12,8% e 9,7%, respetivamente. O canino superior direito mostra desvio palatino e, quando em oclusão, apresenta uma mordida cruzada. Os dentes posteriores (superiores e inferiores) do lado esquerdo apresentam mais desgaste. As características ósseas assimétricas teriam prejudicado a função do complexo craniofacial, nomeadamente através de uma sobrecarga muscular, ligamentar e articular. Além disso, a mordida cruzada poderia ter reforçado esse mau funcionamento. O padrão alterado de mastigação provavelmente explica o desgaste dentário assimétrico.

*Palavras-chave:* Assimetrias mandibulares; Mal posicionamento dentário; Padrão de mastigação; Desgaste dentário.

## Introduction

The skeleton under analysis (PAVd'09 I66) was recovered among the 158 skeletal individuals exhumed from a deposit of urban waste dating from AD 15<sup>th</sup>-17<sup>th</sup> centuries located in Valle da Gafaria, outside the medieval Lagos city walls (Portugal). The

morphometric features of the individuals as well as the archaeological context favour the hypothesis of them being African slaves during the beginnings of the North Atlantic slave trade (for more details, see [Wasterlain et al., 2016](#)).

The individual presents several asymmetries, particularly in the mandible, but

also in teeth. In this paper, such alterations are described and their functional implications in the orofacial structures are discussed. This study is significant since it presents a functional perspective of the stomatognathic system in skeletal remains, a relatively uncommon approach in the osteoarchaeological literature.

### Material and Methods

The Anatomical Conservation Index (ACI) of the individual under study was calculated according to Garcia ([2005/2006](#)). The ancestry was estimated based on cranial morphological and metric characteristics (as detailed in [Navega et al., 2015](#); [Coelho et al., 2017](#)). Sex estimation was achieved through the metric and morphological analysis of the skull and hip bone ([Buikstra and Ubelaker, 1994](#)). Age-at-death was estimated on the basis of morphological changes in the pubic symphysis ([Brooks and Suchey, 1990](#)), auricular surface ([Buckberry and Chamberlain, 2002](#)), and epiphyseal union of the medial clavicle ([Webb and Suchey, 1985](#)).

Both jaws were macroscopically examined under a strong direct light. The following characteristics were observed in the two sides of the mandible according to Ongkana and Sudwan ([2010](#)): the antegonial notch, the gonial angle, and the posterior ramus flexure. All measurements of the mandible (maximum

ramus breadth, minimum ramus breadth, condylar height/maximum ramus height, projective height of ramus, and coronoid height) were taken (in millimetres) with sliding calipers, following Saini *et al.* ([2011](#)). Dental wear was recorded following Smith ([1984](#)).

### Results

The analysis of this skeleton reveals a probable African male aged 30-40 years at death. The ACI score is 86%, which reflects very good preservation. All permanent teeth are present except two upper incisors (the left central and the right lateral), which were lost postmortem. The permanent upper right canine is relatively malpositioned, in a palatal location in relation to the partially remodelled alveolus of the deciduous canine, which is observed in the labial alveolar ridge ([Fig. 1](#)). When in occlusion, the right upper canine presents a crossbite with the ipsilateral mandibular canine ([Fig. 2](#)).

Uneven dental wear is observed in the left and right posterior teeth, both in upper and lower arches, with the teeth from the left side (mean wear =  $2.7 \pm 0.8$ ) more worn out than the right counterparts (mean wear =  $1.9 \pm 0.7$ ).



**Figure 1 - Occlusal view of the maxilla of individual PAVd'09 I66 from Valle da Gafaria (Lagos, Portugal) featuring a relatively mal-positioned permanent right canine, in a palatal location in relation to the partially remodeled alveolus of the deciduous canine, visible in the labial alveolar ridge.**



**Figure 2 - Crossbite occlusion between the permanent right canines of individual PAVd'09 I66 from Valle da Gafaria (Lagos, Portugal).**

The mandible is asymmetrical both morphologically and metrically. A more marked gonial eversion is observed in the left side of the mandible (Fig. 3). The left and right contours of the mandibular lower border are also different, being the right almost straight (Fig. 4A), and the left exhibiting an antegonial notch (Fig. 4B). Although the posterior ramus flexure is present in both sides of the mandible, it appears slightly different, being more pronounced in the left side. Finally, the left coronoid process presents a small bone growth (Fig. 4B). This is not observed in the

right side. All measurements are greater in the left side (Table 1). The greater disparity between the two sides is found in the projective height of the ramus followed by the coronoid height, where the differences reach 12.8% and 9.7%, respectively. The condyles and the temporal surfaces do not exhibit any signs of temporomandibular joint dysfunction. Finally, it is worthwhile noting that the upper incisors of this individual were intentionally modified, with the incisal angles removed.



Figure 3 - Frontal view of the mandible of individual PAVd'09 I66 from Valle da Gafaria (Lagos, Portugal), with a more marked eversion of the left gonial angle.



Figure 4 - Lateral views of the mandible of individual PAVd'09 I66 from Valle da Gafaria (Lagos, Portugal) showing the contour of the mandibular lower border and the posterior ramus flexure: A) the right side exhibits less pronounced antegonial notch and posterior ramus flexure; B) the left shows a deeper antegonial notch and a more pronounced posterior ramus flexure. Note the small bone growth in the left coronoid process.

**Table 1. Dimensions of the mandible of the individual PAVd'09 I66, following Saini *et al.* (2011).**

Measurement	Side	
	Left (mm)	Right (mm)
Maximum ramus breadth	44.4	43.4
Minimum ramus breadth	35.1	33.1
Condylar height/Maximum ramus height	69.0	65.3
Projective height of ramus	58.7	51.2
Coronoid height	55.7	50.3

## Discussion

Among the osteological sample excavated in Lagos, an African male aged 30-40 years exhibits a conspicuous asymmetry of the mandible and teeth. In what concerns the teeth, the permanent upper right canine is malpositioned, in a palatal position in relation to the partially remodelled alveolus of the deciduous canine, which is observed in the labial alveolar ridge. Palatal location of a permanent canine may be related with spaced arches (Jacoby, 1983; Millett, 2008). African individuals are more likely to have longer dental arches, with diastema, than European individuals (Burriss and Harris, 2000). Although this skeleton belongs to an African individual, it does not present any diastemata. Palatal canine locations can also have a significant association with small or missing lateral incisors (Becker *et al.*, 1981; Sacerdoti and Baccetti, 2004; Yan *et al.*, 2013). In this case, the alveolus of the lateral incisor is present but the tooth was lost postmortem, so it is not possible to know if it was small. Although controversial, the palatal canine displacement is also frequently considered to have a genetic basis (Peck *et al.*, 1994; Becker *et al.*, 1995). According to Peck *et al.* (1994) this does not

rule out the influence of environmental factors in the genesis of such anomaly, such as early dentofacial trauma (Brin *et al.*, 1993). In fact, a traumatic aetiology should not be excluded in this individual given that the upper incisors were intentionally filed (for more details concerning the intentional dental modifications recorded in this sample, see Wasterlain *et al.*, 2016). If performed in an early stage of development, this traumatic practice could have led to the dislocation of the permanent tooth under formation.

The incompletely remodelled socket of the deciduous upper right canine reveals that this tooth remained in the oral cavity for many years. Since permanent tooth formation and eruption usually result in the resorption of the deciduous roots, contributing to the loss of the primary tooth (Aktan *et al.*, 2012), it is highly likely that, in this case, the deciduous canine was retained for many years because the permanent canine erupted palatally to its normal location and failed to resorb (or fully resorb) its root. According to the medical literature, retained primary teeth may survive for many years when free from pathology and presenting favourable coronal and root

structure ([Aktan \*et al.\*, 2012](#); [Robinson and Chan, 2009](#)).

At the bone level, the recorded asymmetries are both morphological and metrical. Morphologically, the left side of the mandible shows a more marked gonial eversion, an antegonial notch, a more noticeable posterior ramus flexure, and a small bone growth on the coronoid process. Metrically, all the recorded mandibular dimensions are greater on the left side, being the greatest disparity on the projective height of the ramus, followed by the coronoid height. Mandibular asymmetries develop either embryonically or postnatally, during growth or sometimes even later. The most important aetiologies for such anomalies include embryonic genetic, embryonic non-genetic, postnatal adverse events during growth, adverse events after growth has ceased, and misregulation of growth after birth ([Obwegeser, 2001](#)). According to Obwegeser ([2001](#)), the musculature attached to the mandible also plays an important role in forming the mandible within the genetic pattern. In the present case, and given the nature of the analysed remains, it is not possible to infer the specific aetiology of the mandibular asymmetry. In fact, determining the causal factor is often difficult or impossible even in the living for whom the soft tissues can be evaluated and the life history known ([Obwegeser, 2001](#)).

Although it is not possible to know what caused the asymmetry observed in the teeth and especially in the mandible of this African individual, the functional implications of the asymmetry are worthwhile discussing, namely

the impact that this anomaly might have had during life. Given the set of bony alterations, it is proposed that the function of the craniofacial complex was affected, namely through a muscular, ligamentar and articular overload. Independently of their aetiology, craniofacial asymmetries undoubtedly have biomechanical implications. The asymmetry causes a disequilibrium at the mastication level, namely through a greater muscular power on the more developed side ([Marchesan, 1998](#)). Since gonial eversion depends primarily on the relative strength of the muscles of mastication, namely the masseter ([Loth and Henneberg, 2000](#)), the difference observed between the two gonial angles indicates that this individual had an asymmetric chewing muscular work. Besides, the posterior ramus flexure is also probably associated to a change in the size, strength, or angulation of the muscles of mastication, especially the masseter and medial pterygoid muscles ([Loth and Henneberg, 2000](#)). The bone growth found on the left coronoid process can also reveal an asymmetric overload, in this case specifically associated to the work of the temporalis muscles. In sum, all these findings are suggestive of an altered pattern of mastication.

The presence of a malpositioned canine could have also compromised the orofacial functions, as a correct articulation of the upper and lower canines is essential to canine guidance in laterotrusive movements ([Okeson, 1999](#)). Besides, crossbite can alter the coordination of the masticatory muscles during mastication, reinforcing this malfunction ([Andrade \*et al.\*, 2010](#)).

The differences found in dental wear are consistent with the hypothesis of an uneven pattern of mastication. In the right side, a moderate removal of the cusps was recorded, whereas on the left, the full removal of cusps with some dentin exposure was observed, particularly on the first molars. Such asymmetry could cause degeneration of the temporomandibular joint ([Hillson, 1996](#)). However, as above mentioned, no alterations in the joint region were observed, which may be due to the relatively slight dental wear, the young age of this individual, or the absence of genetic predisposition to this condition. Research conducted on 81 adult individuals from the Lagos' collection ([Rufino, 2014](#)) concluded that severe occlusal wear was unusual (mean dental wear:  $3.0 \pm 1.3$ ), which is consistent with a moderately abrasive diet. For this individual, with a probable functional alteration, a soft or moderately abrasive diet may have allowed for greater protection against muscular, ligamentar, and articular lesions, which would have probably emerged if he had lived long enough.

## Conclusion

The observed mandibular and dental alterations described in the PAVd'09 I66 individual from the Lagos's collection of African slaves are interesting from the palaeopathological perspective, as their biomechanical implications are discussed. Regardless of the possible aetiology of the observed asymmetries, which is unknown, these must have resulted in a malfunction of the craniofacial complex, leading to changes in the pattern of mastication, with an

asymmetrical muscular overload. This can also explain the unequal dental wear between the right and left posterior teeth, as well as the small bone growth in the coronoid process. The set of observed alterations would have hindered a normal mastication, and probably had a negative impact on the quality of life of this enslaved adult individual. This study is significant as it allows a functional perspective of the stomatognathic system in skeletal remains, which is relatively uncommon in the paleopathological literature.

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