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ABSTRACT

Teeth fusion is a developmental anomaly characterized by the union of two, and more rarely, three adjacent teeth. The fusion is caused by the physical pressure between two adjacent teeth during their development due to congenital, inherited, acquired or idiopathic factors. Nowadays, fused teeth occur with a frequency ratio between 0.1% - 1% in permanent dentition and 0.5% - 2.5% in primary dentition, and with an equal distribution between males and females. Fused teeth are a rare clinical finding so there are not standardized clinical protocols and each case should be treated independently. This condition is rare in archaeological populations, likely due to taphonomic processes that cause the lack of information, as well as for the general low occurrence of the defect itself. In the European archaeological literature, there are no reports of two permanent fused teeth so far. Therefore, the present paper represents the first case-study of two fused permanent incisors in the past Europe populations as this anomaly has been recognized in an adult man buried in the Longobard cemetery of Guidizzolo (VI-VII century B.C., northern Italy)**.**

Introduction

Double teeth are a developmental anomaly characterized by the union of at least two adjacent teeth joined by the dentin or pulp and sometimes canals, called also “synodontia” or “twinning” (Sekerci et al., 2011). This developmental anomaly can occur in two different ways: either gemination or fusion. Gemination originates when one tooth bud attempts to split into two, whereas fusion occurs when two tooth buds touch each other and subsequentially join (Neves et al., 2002). Gemination and fusion may look identical and a differential diagnosis is difficult to make, especially when a supernumerary tooth is involved (Tritsaroli, 2018). For this reason, the terms ‘double formation’ or ‘double teeth’ are used to indicate both fusion and gemination. However, fusion may be differentiated from gemination by radiographic analysis or the observation of avulsed teeth. It has been proposed that in case of fusion, the crowns are joined by enamel and/or dentine and they have two roots or two root canals merged in a single root. Instead, gemination can generate two crowns and a single root canal and pulp (Sekerci et al., 2011). Fusion can be distinguished in complete or incomplete, depending upon the stage of development of teeth at the time of union (Tritsaroli, 2018). The first type, also called *fusio totalis*, begins before the calcification process and the crown incorporates the features of both teeth involving enamel, dentin, cementum and pulp. In this case the fused teeth appear unite to form an almost normal single tooth, with an enlarged crown. The incomplete type (*fusio partialis*) can be at root level if it occurs after the calcification of the two separate crowns, with or without the involving of the pulp canals (*partialis radicularis*) or can be at crowns level (*partialis coronalis*). In incomplete fusion it is possible to distinguish the outline of the two different crowns, due to the presence of grooves and sulcus (Agarwal et al., 2015; Hülsmann et al., 1997; Rajashekhara et al., 2010; Schuurs & Van Loveren, 2000).

The aetiology is usually searched in congenital, inherited, acquired or idiopathic factors (Kavya et al., 2019). However, other factors may give origin to the double teeth, such as thalidomide embryopathy, hypervitaminosis, fetal alcohol exposure or syndromes such as trisomy 21, orodigitofacial syndrome and Pierre–Robin syndrome (Kavya et al., 2019).

Fusion occurs more often in primary teeth, with particular involvement of mandibular incisors and canines, while gemination and supernumerary teeth are usually found in the maxillary arch (Gurri & Balam, 2018; De Jonge, 1955; Whittington & Durward, 1996). This suggest that the two defects may be under different genetic control and that they result from independent event: a mandibular process of tooth reduction (fusion) and a maxillary process of tooth enlargement (gemination) (Gurri & Balam, 2018; Tritsaroli, 2018). Nowadays, double teeth occur with a frequency ratio between 0.1% - 1% in permanent dentition and 0.5% - 2.5% in primary dentition (Castelino et al., 2015; Wu et al., 2019). This defect has an equal distribution between males and females and it seems to highly spread

among Asian and South American population compared to Caucasian one (Kavya et al., 2019). It is very rare for this defect to bilaterally occur (Tomizawa et al., 2002). Caries or calculus formation can be related due to the presence of deep grooves (Kavya et al., 2019).

Fused teeth are rare in archaeological populations. It is likely due to diagenetic and taphonomic processes that may alter the preservation of human remains, as well as for the general low occurrence of the defect itself. Only few cases have been documented and they have been always pointed out in deciduous dentition (Benazzi et al., 2010; Padgett, 2018; Silva & Silva, 2018; Smith & Wojcinski, 2011; Tritsaroli, 2018) , except for a male mummy from an Egyptian site which presents upper permanent incisors fusion (Forshaw, 2019) (Table 1). In this work, we report the first archaeological case of permanent double incisor in Europe.

Case report

During some roadworks in Guidizzolo (Mantova, northern Italy), a Longobard necropolis (VI-VII century B.C.) was discovered and then investigated.

The archaeological excavation led to a total of 93 burials orientated from west to east, on parallel rows, that seemed to reflect Germanic usage. The 93 individuals (34 non-adult, 41 adult and 18 indeterminates) are still under studies at the Laboratory of Osteoarchaeology and Palaeoanthropology of the Department of Cultural Heritage (University of Bologna).

During the osteological analysis of the human remains, a case of union between two permanent mandibular teeth (RI_1 and RI_2) was recognized on the individual n. 58 (Fig. 1). The mandible suffered several postmortem injuries: the break of the right condyle, of the mandibular body and of the fused teeth alveoli, that are avulsed from the mandible. (Fig. 2). Teeth present a generalized deep wear that exposes large areas of dentine and that reaches the root in some cases.

Reabsorption of the lower right second molar (RM_2) proves that it fell before death. Instead, the lower left second molar (LM_2) is not present because it has been sampled for aDNA's analysis. All the other teeth are present except for the third molars that are probably absent for agenesis. The lower first right molar presents an enamel caries on the mesial side.

Anthropological analyses were carried out on the individual n. 58 in order to determine the biological profile. Sex determination based on the sexualization index for the skull (Acsadi & Nemeskeri, 1970) and hip bone morphology (Bruzek, 2002) led to establish that this individual was a man. Estimation of age at death based on the cranial suture obliteration method (Acsadi & Nemeskeri, 1970; Meindl & Lovejoy, 1985), dental wear (Lovejoy, 1985) and the degeneration of the auricular surface (Schmitt, 2005) reveal that the individual died at approximately 35-50 years.

Fused teeth

The double teeth, RI_1 and RI_2 (Fig. 1), were macroscopically analysed under normal light conditions and through radiographies. Both teeth seem to have normal dimensions and the union involves both the upper third of the crowns and the apical part of the roots, while the inter-radicular space was occupied by alveolar bone. A calculus deposit is present in the buccal and lingual side of the interproximal area. In occlusal view, the advanced degree of dental wear shows shared dentine between the two teeth. Thanks to the presence of the entire mandible, we can exclude the presence of supernumerary teeth.

The radiographic examination (Fig. 3) was executed through analogic radiographic system. The X-ray film (DF58, Kodak) was impressed by 0.250 ms X-ray beam set at 70kV and 8mA.

The sample was positioned with the buccal side facing the film, and the x-ray film was then processed using the dedicated reagents. Each dental crown has its own pulp chamber, which seem to be separated and independent. This could mean that the fusion process occurred during the later stage of morph-differentiation (Kavya et al., 2019; Mehta, 2019). Two unconnected roots depart near the cement enamel junction and each root appears to have a single endodontic canal system. In the apical area of the teeth, the two roots have a strict anatomical proximity and, in the last millimetres, they are adherent. Two separated apexes are present. No pathology signs can be detected from the radiograph.

These results lead to identify the fused RI1 and RI2 as a case of *partialis coronalis* fusion (Knežević et al., 2002).

Additional age estimation was executed following the method published by Kvaal et. al (1995). Tooth length, root length, pulp and root widths of the lateral mandibular incisor were measured trough a digital calibre (INSERIRE MARCA) directly on the X-ray film. Six ratios between the measures were calculated as described by Kvaal and colleagues and the obtained values were implemented in the age estimation regression formulae for lateral lower incisors: 106,6 – 251,7(M) – 61,2(W-L) – 6,0(G) (Table 2). The estimated result has been of 31,3 years. This value could suggest that the man could be even a little bit younger than the age estimated through previous anthropological analysis (Kvaal et al., 1995). However, some limitations exist in this technique since several physiological factors could affect the pulpal extension and so the age estimation accuracy.

Conclusion

This paper describes a case of double permanent incisors in an early Medieval population of Northern Italy. The diagnosis is based on macroscopical and radiological examination. Both gemination and fusion were considered for our diagnosis because their causes are more prevalent in primary dentition than in the permanent dentition, with incisors being more affected (Guimarães Cabral et al., 2008). Clearly, the described individual is a case of fusion, involving specifically dental

crowns (*partialis coronalis).* Indeed, the two pulp chambers are separated, the roots are bifurcated in their lower extremity, and the crowns are separated by buccal and lingual grooves. The fusion process occurred during the later stage of the teeth development since only the crowns are merged and the roots are independent. As shown by the dental wear, the dentine of both crowns is confluent. The presence of the groove predisposed the calculus formation which could have led to periodontal damage. However, no sign of decay is detected.

Nowadays, several treatment options have been described in the dental literature (Hulsmann et al., 1997; Malcic & Prpic-Mehicic, 2005; Olivan-Rosas et al., 2004; Stillwell & Coke, 1986). When a *partialis coronalis* fusion occurs, two different treatment approaches can be adopted. If a supernumerary tooth is involved, a surgical section followed by extraction of the supernumerary part is recommended. In that case, if the pulp chambers are connected, root canal treatment of the remaining part is performed. However, when two permanent teeth are fused, like in this case report, crowns' hemi-section and crowns' reshaping could be indicated. Before that, root canal treatment is mandatory for both teeth. Overall, however, fused teeth are a rare clinical finding, so there are not standardized clinical protocols and each clinical case should be treated based on the patient special needs (Tuna et al., 2009).

Clinical cases of double teeth are often described in the modern literature (Castelino et al., 2015; Guimarães Cabral et al., 2008; Kavya et al., 2019; Neves et al., 2002; Sekerci et al., 2011; Tomizawa et al., 2002; Wu et al., 2019), but up to now this anomaly was not recorded in the permanent dentition of past European populations until now. The only documented ancient case involving permanent dentition concerns a 4000 years old Egyptian mummy with upper incisors fusion (Forshaw, 2019). Consequently, as far as we know, this is the first case of fusion of two permanent lower incisors discovered in archaeological contest.

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REFERENCE	TEETH INVOLVED	AGE AT DEATH	SITE	CHRONOLOGY
Forshaw, 2019	LI^1 and LI^2	40 years	Deir Rifeh – Cairo (Egypt)	1985 – 1773 BC
Tritsaroli, 2018	RdI_1 and RdI_2	18 (± 6) months old	Rema Xydias - Platamonas (Greece)	Late Bronze Age
Silva & Silva, 2018	LdI_2 and Ld_C	3-4 years	Miroiço - Sintra (Portugal)	2nd – 4th century AD
Padget, 2010	LdI^1, LdI^2, Ld^C	9 months old	Law's Site – Alabama (USA)	1540 – 1715 AD
Benazzi et al., 2010	RdI^1 and RdI^2	5 years	S. Martino in Rivosecco - Borgotaro (Parma, northern Italy)	14th – 18th century AD
Smith & Wojcinski, 2011	RdI_2 and Rd_c	5-6 years	Cherry - Tennessee (USA)	2500-1000 BC
	RdI_1 and RdI_2	3.5-4.5 years	Cherry - Tennessee (USA)	
	RdI_2 and Rd_c	0.5-0.75 years	Oak View Landing - Tennessee (USA)	
	LdI_2 and Ld_c	4.5-6 years	Kays Landing - Tennessee (USA)	
	LdI_1 and LdI_2 RdI_2 and Rd_c	1 years	Toqua - Tennessee (USA)	1300-1550 AD
	LdI_2 and Ld_c	1.5-2 years	Toqua - Tennessee (USA)	
	LdI_1 and RdI_1	2-2.5 years	Toqua - Tennessee (USA)	
	RdI_1 and RdI_2	1-1.5 years	Toqua - Tennessee (USA)	
	LdI_2 and Ld_c RdI_2 and Rd_c RdI^2 and Rd^c LdI^1 and LdI^2	3-4 years	Citico - Tennessee (USA)	

Table 1. Archaelogical case of fused incisors found in literature.

MEASURES (mm)		RATIOS	
Tooth length	**17,19**	P (pulp length/root length)	**1,44**
Pulp length	**14,03**	T (tooth length/root length)	**0,57**
Root length	**9,72**	R (pulp length/tooth length)	**0,82**
Root width in A	**3,51**	A (pulp width/root width in A)	**0,18**
Root width in B	**2,96**	B (pulp width/root width in B)	**0,11**
Root width in C	**3,17**	C (pulp width/root width in C)	**0,06**
Pulp width in A	**0,63**	M (mean value of all ratios)	**0,53**
Pulp width in B	**0,32**	W (mean value of width ratios from levels B and C)	**0,09**
Pulp width in C	**0,20**	L (mean value of the length ratios P and R)	**1,13**

Table 2. Measures executed on the X-ray plate and ratios (Kvaal et al., 1995). A: enamel-cementum junction; B: midpoint between level C and A; C: mid-root level. Estimated years (lateral incisor) regression formulae = 106,6 – 251,7(M) – 61,2(W-L) – 6,0(G) (where G: male = 1, female = 0).

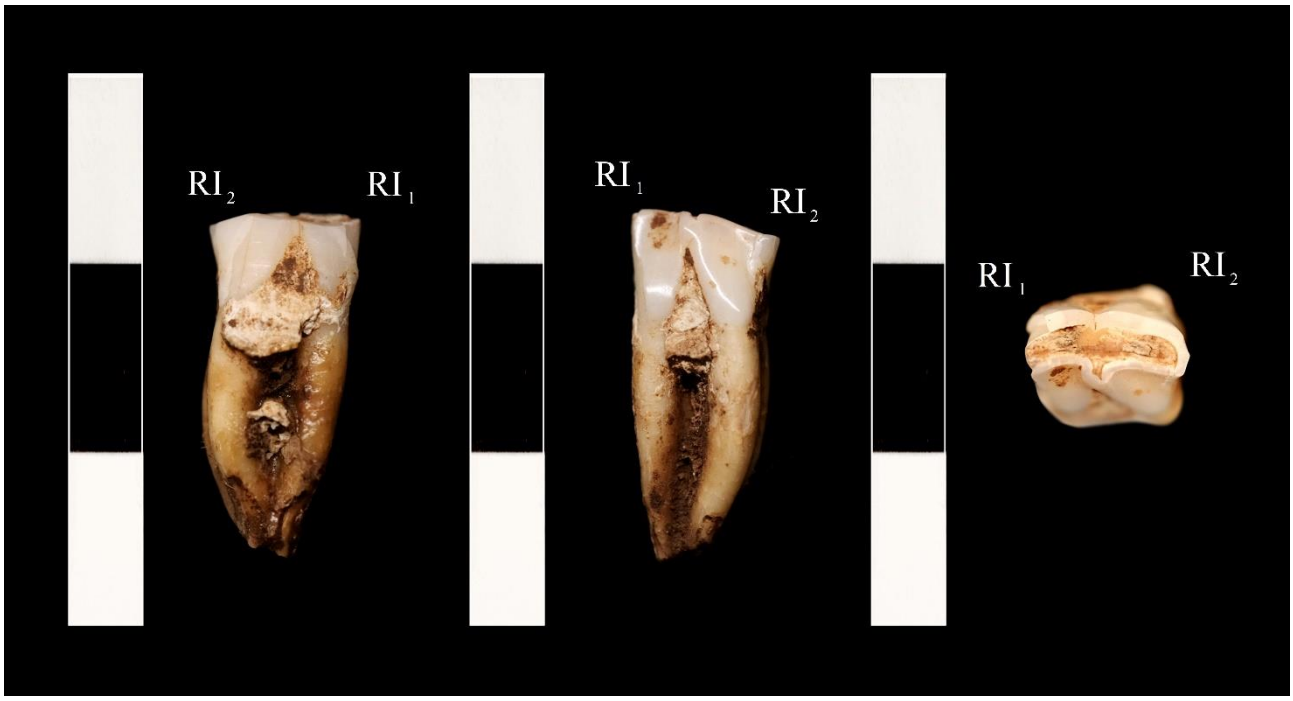

Figure 1 Buccal view (on the left), lingual view (in the center) and occlusal view (on the right) of the two permanent fused teeth.

Figure 2 Occlusal view of the mandibular dentition. Fused permanent teeth are the first and the second right lower incisor which are not in place.

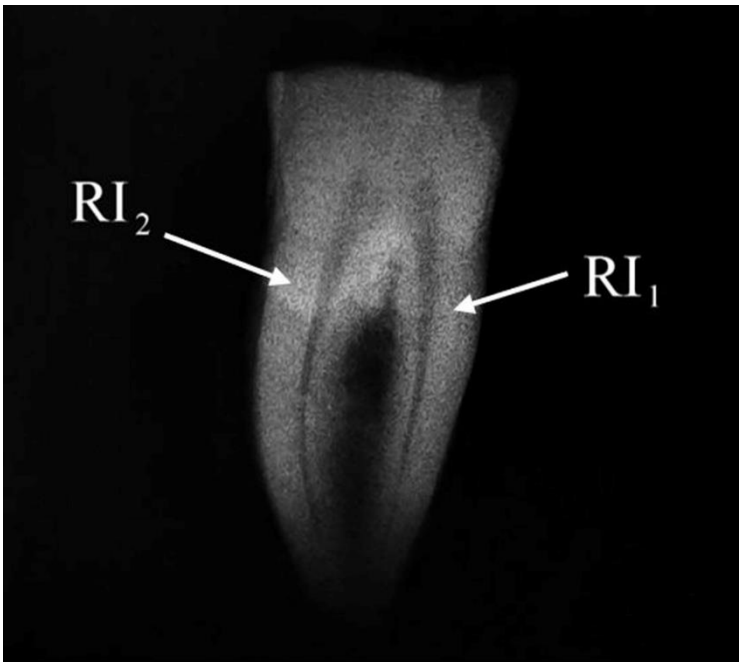

Figure 3 Radiograph of the two fused permanent teeth RI_1 and RI_2 (buccal view).