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THE POTENTIAL OF VIRTUAL IMAGING IN THE UNDERSTANDING OF NORMAL AND ABNORMAL TUSK STRUCTURE IN WILD BOAR (*SUS SCROFA* L.)

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Konjević, D., Njemirovskij, V., Radovčić, J., Severin, K., Manojlović, L., Marotti, M. & Slavica, A.: The potential of virtual imaging in the understanding of normal and abnormal tusk structure in wild boar (*Sus scrofa* L.). Nat. Croat., Vol. 17, No. 4, 265–272, 2008, Zagreb.

Results of non invasive virtual imaging of normal and altered wild boar tusks are presented. Pathologically altered tusk structure is presented for two pairs of mandibular canines that experienced different traumatic impacts and in one lower mandible with a complete loss of the right lower canine. Wild boar tusks represent a valuable material for dental pathologists due to their characteristic position and consequent predisposition to injury, their enormous reparative potential and the fact that they are collected and kept as trophies over extended periods of time. However, their value as trophy often limits the possibility of analysis of internal structural changes by destructive methods. In this situation, the use of non invasive methods can provide insights into the nature of pathological and reparation processes related to traumatic impacts on wild boar tusks.

Key words: wild boar, tusk, virtual imaging, structure analysis

Konjević, D., Njemirovskij, V., Radovčić, J., Severin, K., Manojlović, L., Marotti, M. & Slavica, A.: Potencijal virtualnog prikaza u razumijevanju normalne i promijenjene građe kljova divljih svinja (*Sus scrofa* L.). Nat. Croat., Vol. 17, No. 4, 265–272, 2008, Zagreb.

U radu je dan virtualan prikaz normalne i promijenjene građe kljova divljih svinja, kao neinvazivna metoda vizualizacije strukturalnih promjena. Normalna građa kljova predstavljena je kompjuterskom tomografijom donjih očnjaka, dok su patološki promijenjene kljove zastupljene sa dva para donjih očnjaka nakon ozljede te jednom donjom čeljusti sa potpunim gubitkom desnoga očnjaka. Kljove divljih svinja predstavljaju vrijedan materijal za proučavanje zubne patologije zahvaljujući karakterističnom položaju i posljedičnoj sklonosti ozljedama, izrazitom reparacijskom potencijalu te ponajviše dugotrajnom čuvanju u svojstvu trofeja. Međutim, njihova vrijednost kao trofej često umanjuje mogućnosti proučavanja. S druge pak strane virtualan prikaz zuba osigurava neinvazivnu vizualizaciju promjena u građi, razumijevanje patoloških i reparacijskih procesa, mjerenje dijelova zuba, kao i odvajanje i detaljan pregled pojedinih dijelova.

Ključne riječi: divlja svinja, virtualan prikaz, proučavanje građe

INTRODUCTION

Tusks of mammals are continuously growing (elodont) anterior teeth (incisors, canines) that protrude from the mouth (STEENKAMP, 2003). In the case of the male wild boar, both the maxillary and the mandibular permanent canines are developed as tusks (THENIUS, 1989; STEENKAMP, 2003). Their opposite (antagonistic) position results in constant attrition, thereby maintaining the normal length and functional shape of the teeth. Wild boars use their tusks as weapons in intraspecific and interspecific fights as well as for marking trees. In addition, tusks are used as levers to lift up larger stones or other heavy objects in order to get access to food items located below them (BRIEDERMANN, 1990). The various ways in which tusks are used, in combination with the fact that they protrude from the mouth, makes them particularly prone to injury. On the other hand, due to their continuous growth, enormous reparative potential and long-time preservation as trophies, wild boar tusks constitute a valuable material for studies of dental pathology and regeneration. These advantages have already been recognized, resulting in the description of a variety of pathological conditions in these teeth (MILES & GRIGSON, 1990; PALÁŠTHY & PALÁŠTHY, 1991; HORWITZ & DAVIDOVITZ, 1992; KIERDORF & KIERDORF, 2003; STEENKAMP, 2003; KIERDORF *et al.*, 2004a; KIERDORF *et al.*, 2004b; KONJEVIĆ *et al.*, 2004a; KONJEVIĆ *et al.*, 2004b; KONJEVIĆ *et al.*, 2006). However, due to their value as trophies it is often not possible to use destructive methods for a proper analysis of the pathological conditions in wild boar tusks. In this situation, the application of non-destructive two-dimensional and three-dimensional (3D) virtual imaging of teeth is opening up new possibilities for analyzing normal and pathological dental structures and thereby gaining better insights into the reparative and regeneration processes of fractured wild boar tusks. In contrast to the situation in human dentistry where this method is applied routinely (HAJEER *et al.*, 2004) it is still rarely used in laboratory animals (i.e. VIRIOT *et al.*, 1997), livestock or wildlife species. The aim of this work was to present the potential of virtual imaging as a non-destructive tool for studying dental pathology in wild boar teeth.

MATERIAL AND METHODS

Four pairs of mandibular wild boar canines were collected during regular hunting operations in hunting grounds in the Republic of Croatia and studied using computed tomography (CT) and high-resolution micro-computed tomography. One pair of lower canines exhibiting growth arrest of traumatic origin and the rostral part (starting from the fourth premolar) of a wild boar mandible with complete absence of the right canine were analyzed because of the alterations in structure observed. Both of the mentioned cases were previously described based on macroscopic observations (KONJEVIĆ *et al.*, 2006). In brief, observed growth arrest of the right mandibular canine was attributed to traumatic impact to the tooth with consequent inflammation and partial necrosis of the dental pulp. Observed tooth surface irregularities and distinct ledges that demarcate the proximal from the distal portion of the tooth are indicative of periodontal processes and temporary growth arrest. In the case of the wild boar mandible, the right canine was completely lost probably due to the congenital malposition of the tooth in question (KONJEVIĆ *et al.*, 2006). Normal tusk structure was depicted by CT images of 4 maxillar and two mandibular canines and high–resolution micro-computed tomography of right mandibular canine. High-resolution micro-computed tomography of one wild boar maxilla represented the normal structure of the right canine and abnormally shap-

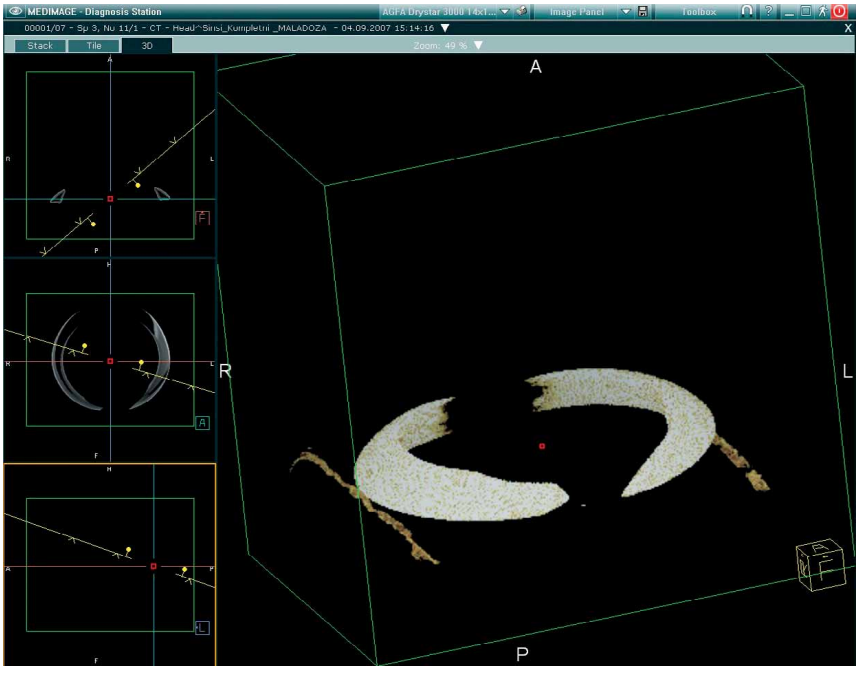

Fig. 1. Normal lower canines of wild boar, three-dimensional model, virtual cross and longitudinal section of the same canines.

Fig. 2. High-resolution CT of lower jaw, showing one fractured and one normal canine.

ed duplicated left canines (supernumerary) (Fig. 1). High-resolution micro-computed tomography was performed with a BIR ACTIS 225/300 high-resolution industrial CT (225 kV), using resolutions as low as 5 microns. The use of this scanner was kindly provided by Dr. Jakov Radovčić (Max Planck Institute for Evolutionary Anthropology, Leipzig). CT image data were processed and analyzed by 3D VEPRO Medimage® (VEPRO AG, Pfungstadt, Germany) software. Measurements were performed directly in the 3D VEPRO Medimage® (VEPRO AG, Pfungstadt, Germany) software.

RESULTS AND DISCUSSION

Use of computed tomography enabled a non-destructive visualization (and reconstruction) of the overall tooth form and the internal tooth structure in a 3D manner in normal and pathologically altered wild boar tusks (Figs. 1–5). Using this method it was possible to confirm that growth arrest caused by a traumatic impact on the right lower canine (A in Fig. 3) resulted in the formation of tertiary dentine and in the formation of a dentinal plug (B in Fig. 3). However, this dentinal plug did not completely separate the distal from the apical portion of the fractured canine in question (C in Fig. 3), thereby leaving the path for bacterial invasion open. In consequence, the reparative processes in this tooth were finally overcome by bacterial invasion. Fig. 1 shows some of the cross and longitudinal sections of the normal mandibular canines along with their 3D projection. Fig. 5 demonstrates the distribution of dental hard tissues and the outline of the pulp chamber within the tusk, as well as the possibility for morphological measurements of different layers (tissues) on different areas.

Fig. 3. A pair of lower canines with severe trauma of the right (A). Virtual »walk-through" shows layers of tertiary dentine (B) and still exposed pulp cavity (C).

During previous studies on tusk pathology in wild boar (PALÁŠTHY & PALÁŠTHY, 1991; HORWITZ & DAVIDOVITZ, 1992; KIERDORF & KIERDORF, 2003; STEENKAMP, 2003; KIERDORF *et al.*, 2004a; KIERDORF *et al.*, 2004b; KONJEVIĆ *et al.*, 2004a; KONJEVIĆ *et al.*, 2004b; KONJEVIĆ *et al.*, 2006) analysis of the pathological tooth structures were mainly based on macroscopic and x-ray examinations. Destructive methods (i.e. preparation of ground sections) that could provide deeper insights into the prevailing pathological processes and the reparative responses of the dental tissues were mostly not permitted in these cases. In this situation, the use of the non destructive methods presented in this paper can provide a valuable tool for a proper diagnosis of these processes.

Since its invention in 1973 by Sir Godfrey Hounsfield (HOUNSFIELD, 1973) computed tomography is a well-known medical technique for non-destructive examination of the internal morphology of soft tissue and skeletal structures The observed

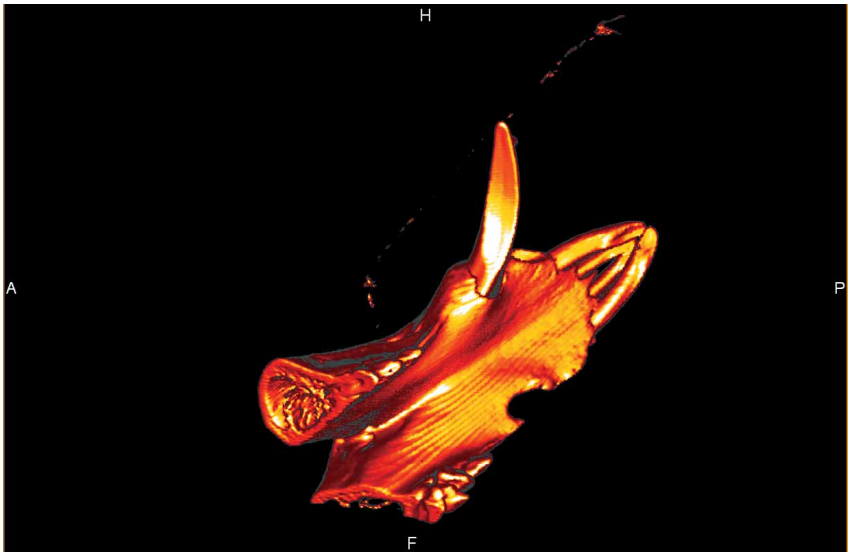

Fig. 4. Three-dimensional model of one part of the lower jaw with complete loss of the right canine.

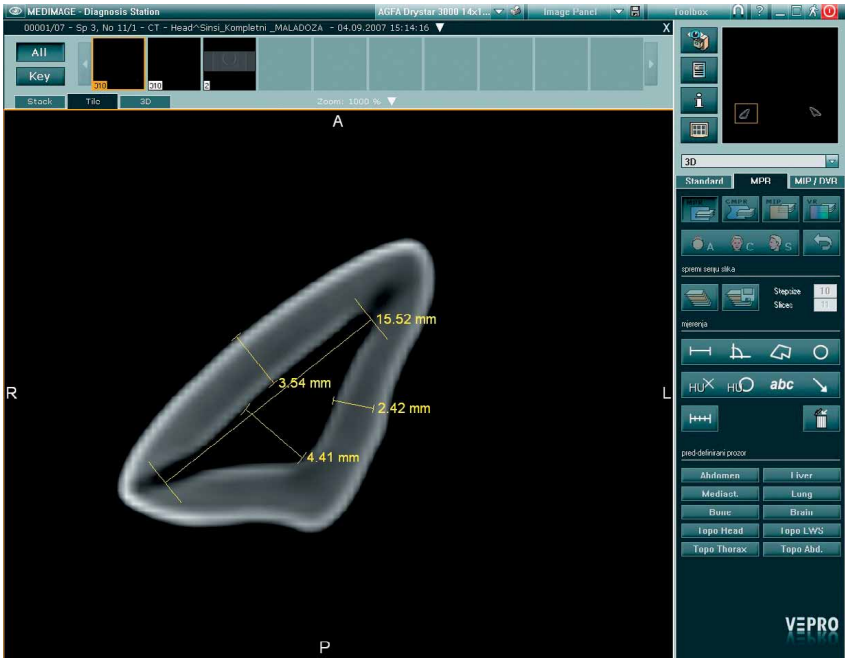

Fig. 5. Cross-section of lower canine showing wide pulp chamber and the potential of 3D imaging for morphometrical analysis.

disadvantages of these methods were described as time consuming and less cost efficient when compared with conventional radiography, while radiation exposure is the main limiting factor for regular usage of CT in orthodontics (KAU & RICHMOND, 2005). However, these disadvantages do not represent a problem in the case of post mortem analysis for scientific purposes.

Finally we conclude that application of CT and three-dimensional imaging can be used for quantitative analysis of the shape and volume of the pulp cavity and for detailed analysis of structure and distribution of different dental thereby allowing for a better understanding of the pathological and reparative processes related to tooth fractures.

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