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Technical note

The use of the Anatomage Table for improving forensic odontology education and training

Corrado Calì [a,b], Emilio Nuzzolese [c,*]

[a] Department of Neuroscience "Rita Levi Montalcini", University of Turin, Turin 10126, Italy
[b] Neuroscience Institute Cavalieri Ottolenghi, Orbassano 10043, Italy
[c] Department of Sciences of Public Health and Pediatrics, Section of Forensic Medicine, Human Identification Laboratory, University of Turin, Corso G. Galilei 22, Turin 10126, Italy

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ABSTRACT

Human and animal anatomy can benefit from the use the life-sized three-dimensional (3D) images of the Anatomage Table which is an intuitive touchscreen that allows virtual dissection, interactions, and control features, including the turning on and off of selected structures categorized on various cadaver models.

This technical note reports the innovative application of the Anatomage Table in a forensic odontology training program, allowing an accurate and high-resolution study and observation of the head, skull, jaws, and teeth, for the purpose of teaching dental autopsy procedures and standardized collection of dental autoptic parameters, as well as to familiarize with radiological images. Moreover, we propose virtual post-mortem dental data collection as an efficient tool in forensic odontology education and training, as an adjunct onsite as well as remote learning resource.

The Anatomage (Anatomage, Inc., Santa Clara, CA) is a modern digital tool for studying human and animal anatomy using life-sized three-dimensional (3D) reconstructions obtained from segmentation of multimodal images (CT scans, MRI, photogrammetry) [1,2]. The Anatomage Table is equipped with an intuitive touchscreen similar to smartphones and tablets, allowing for virtual dissection with various interactive tools. Thanks to the visibility control feature which enables users to apply different filters to preloaded CT scans, as well as custom DICOM datasets, to highlight soft, rather than hard tissues using different voxel rendering modalities (Fig. 1). Users can then virtually dissect selected structures by applying arbitrary clipping planes (Fig. 2) [3]. The Case Library contains an extensive collection of CT and MRI scans including skull, jaws, teeth, and 4D scans showing changes over time. Forensic odontology postgraduate. programs include human identification process through collection and analysis of dental data. Skull and jaws anatomy is a fundamental element in the process of teaching and training odontologists, as for any other physicians [3–5]. The forensic odontology education must rely on hands-on training and exercises on cadavers, on which are performed head dissections, dental autopsies, and radiographs [6]. Training on cadavers may be challenging for most dentists wishing to attend a forensic odontology program, given the limited availability of cadaver lab programs in the world and the cost of such training in medical and dental schools, and it is becoming increasingly common to study using virtual teaching [7,8]. Following COVID-19 pandemic, which gave a push towards the use of augmented reality in medical disciplines such as surgery [9], anatomy followed the same trend and is indeed already taught through augmented reality [10] in conjunction with CT scans of cadavers [11]. The Anatomage Table marks a turning point in the learning process of post-mortem dental and radiological data collection and analysis (Fig. 3) utilizing the 3D reconstructions of the head, the contrast-enhanced CT scans and the radiographs on the selected planes (Fig. 4) [12]. A forensic odontology training program must provide to postgraduates with a practical component to allow for the acquisition of skills and training on a methodological approach in age estimation, bite mark analysis, and dental identification. Training in the dental autopsy, forensic radiology, and teamwork with law enforcement agencies and other forensic experts may also be included. The Anatomage Table allows us to visualize and analyze, with accuracy and high resolution, the head, skull, jaws, and teeth and identify reference points allowing critical measurements, as well as to familiarize students with radiological images for the purpose of comprehending the basics of standardized collection of dental autoptic parameters (Figs. 4–6). Current dental case library contains scans of skulls and teeth including radiographic image

* Corresponding author.
E-mail address: emilio.nuzzolese@unito.it (E. Nuzzolese).

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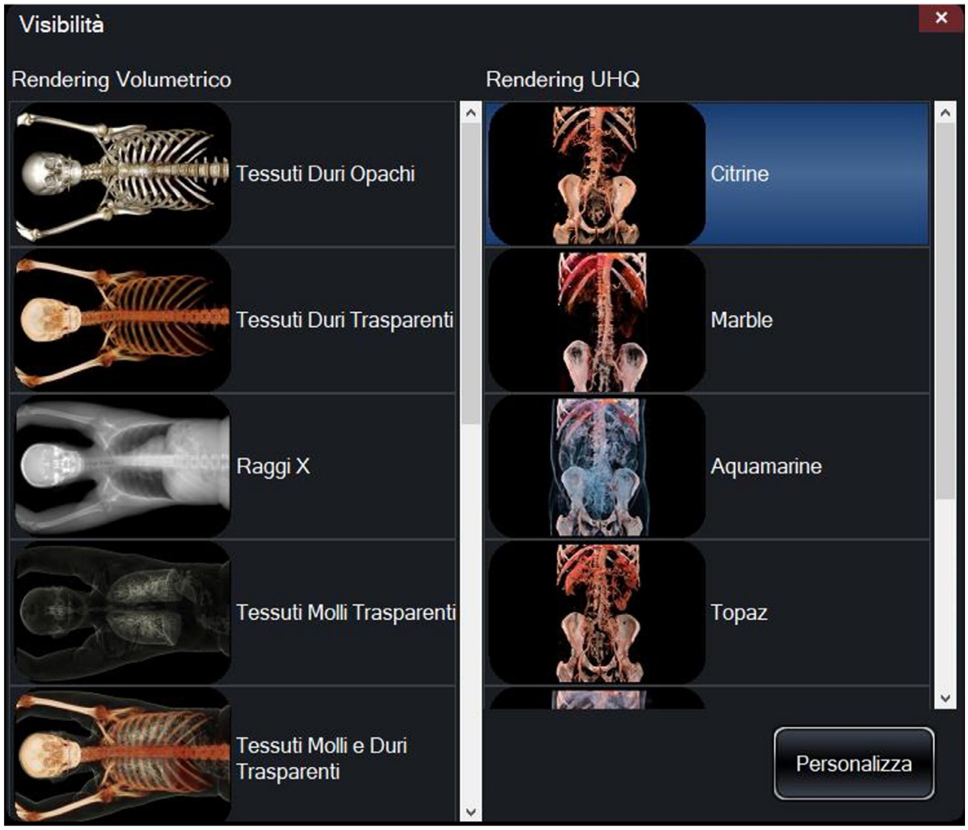

Fig. 1. Screenshot from the *Anatomage* showing the different rendering settings allowing to apply different filters to the datasets for highlighting different structures in 3D.

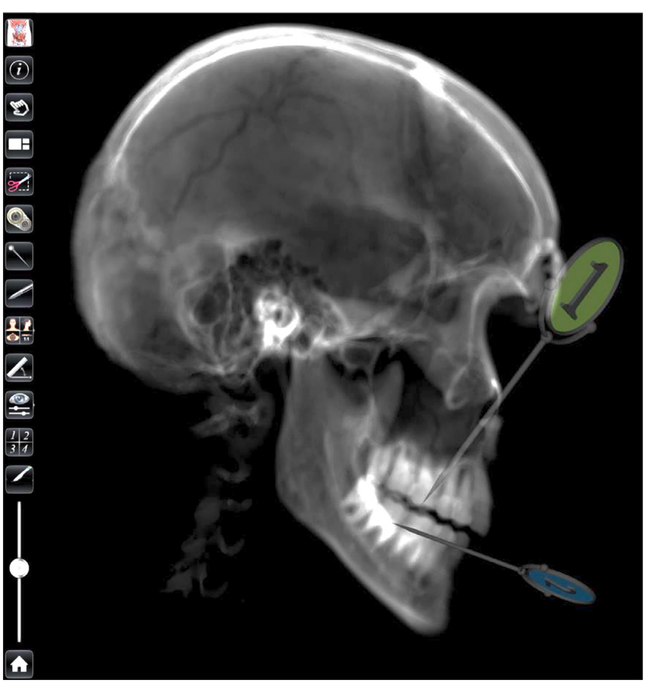

Fig. 2. Screenshot from the *Anatomage* Table showing a 3D rendering of a CT scan DICOM dataset from the library pre-set applying the 'Transparent Hard Tissue' rendering filter. A parasagittal cut plane has been applied to the full dataset, together with two markers allowing to highlight structures of interest for further analysis.

stacks from CT scans. For this reason, post- graduates in forensic odontology can experience the process of performing a dental autopsy, observing jaws and teeth (Fig. 4), which can be rotated and dissected using arbitrary clipping planes (Fig. 2) and enlarged with the advantage of keeping proportion and calibration as the calibration of the measurement tool increases together with the magnification of the image itself (Fig. 5). Soft tissues and jaws can be dissected allowing a detailed observation of any dental anomalies, crown morphologies and dental treatments (Figs. 2, 4, 5), choosing as dissected plane the occlusal plane, which will allow the clear observation of dental arches (Fig. 6). Although there are no periapical and panoramic X- ray images, radiography-like images of the skull can be obtained from the X-Ray filter volume rendering (Figs. 2, 5A, 6), removing one side, and cropping on the interested area to be observed in order to gather information on any anomalies, periapical pathologies, dental treatments and analyze missing teeth and alveoli. Another feature which enhances the post-mortem dental data training process, is the opportunity to take snapshots of the area observed, thus also allowing the documentation of the case study and filling of data sheets and identification forms. The Anatomage virtual dissection should be considered an adjunct training tool as it cannot replace the *in-situ* examination of cadavers of a training program in forensic odontology.

The Anatomage Table could also incorporate real forensic caseworks uploading DICOM datasets such as whole-body CT scans or Cone Beam datasets, widely used in odontology (Fig. 7), thus allowing a remote autopsy following the *virdentopsy* [13] and *virtopsy* [14] concepts. In authors' opinion the Anatomage Table should also incorporate a forensic odontology training library, including al "L" shaped measurement tool (Fig. 5), dental imaging used also in dentistry, such as periapical and panoramic X-ray images, and identification forms with the odontogram to be compiled as part of the training.

Fig. 3. Photo of a live training session with postgraduates of a forensic odontology course.

Conclusions

The Anatomage table for virtual post-mortem dental data collection can be used as an effective and adjunct tool in forensic odontology education and training, and its use is recommended as an adjunct onsite as well as a remote learning resource. The tool could also be used for real case works for remote consultations and a second expert opinion.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Corrado Calì: Investigation, Funding acquisition, Resources, Software, Validation, Visualization, Writing & review & editing. **Emilio Nuzzolese:** Investigation, Funding acquisition, Conceptualization, Visualization, Writing & original draft, Writing & review & editing.

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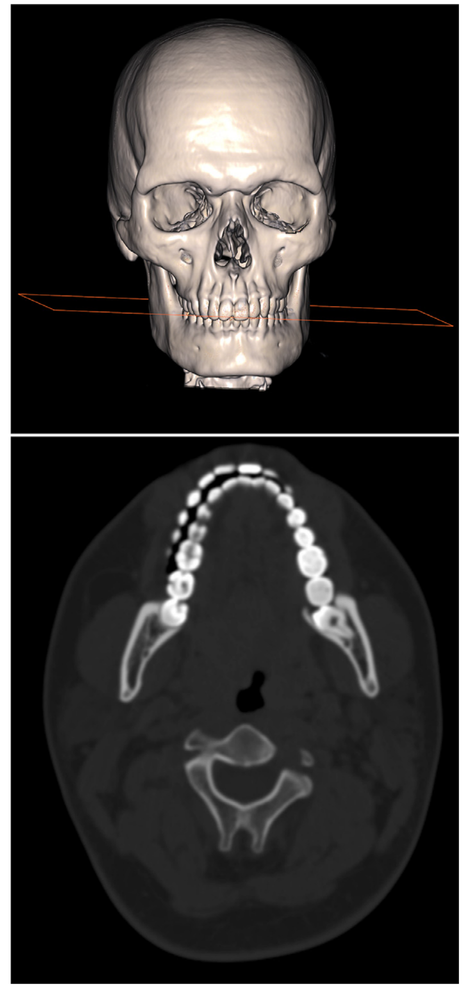

Fig. 4. Snapshot from the *Anatomage* Table of a CT scan DICOM dataset from the library pre-set. On top is the 3D volume rendering of the entire skull using the 'Opaque Hard Tissue' pre-set. Bottom, one planar image, at the level of the lower portion of the ramus of the mandible and the superior dental arch, from the original CT scan acquired to reconstruct the skull on the left. The z level of the transversal plane is highlighted on the 3D reconstruction by the presence of an orange plane.

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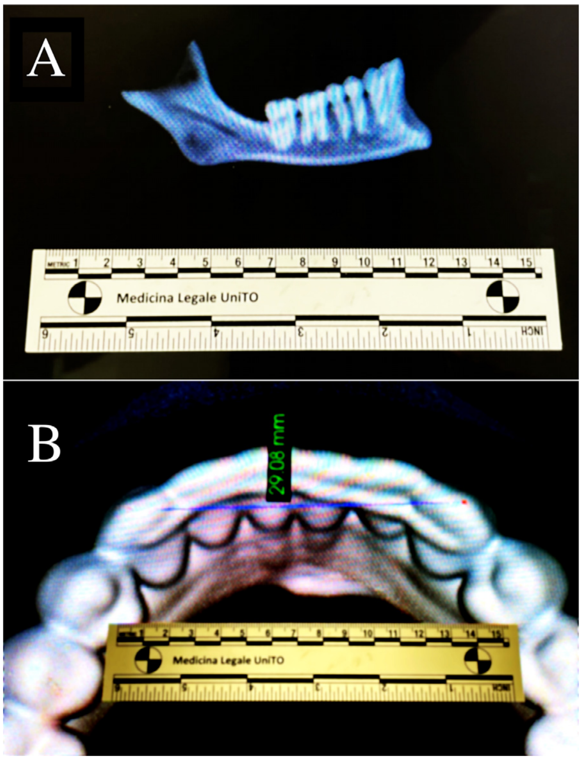

Fig. 5. Analysis of a digitally dissected jaw in *Anatomage.* By using virtual dissecting tools, the jaw was isolated to be analyzed. A. Sagittal view of the jaw rendered using the X-Ray filter. The forensic scale at the bottom shows that the jaw is shown at its original size. B. Coronal view of the jaw rendered using the "Opaque Hard Tissue" filter. The enlarged view eases measurements of parameters of interests, such as the distance between the canine teeth. By using a forensic scale to set the field of view (bottom), it is possible to show how measurements are rescaled and preserved on the digital enlarged jaw, although its apparent size is roughly 4 times higher.

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Fig. 6. Digital dissection of the jaw to highlight the maxillary arch. Snapshots with the *Anatomage*, bottom view of three 3D renderings from the same skull. Top, the skull is rendered in black and white using the opaque hard tissue filter; at centre, using the same rendering settings, cervical spines and the jaw have been digitally dissected to highlight teeth from the maxillary arch; bottom, the same dataset rendered using X-ray filter.

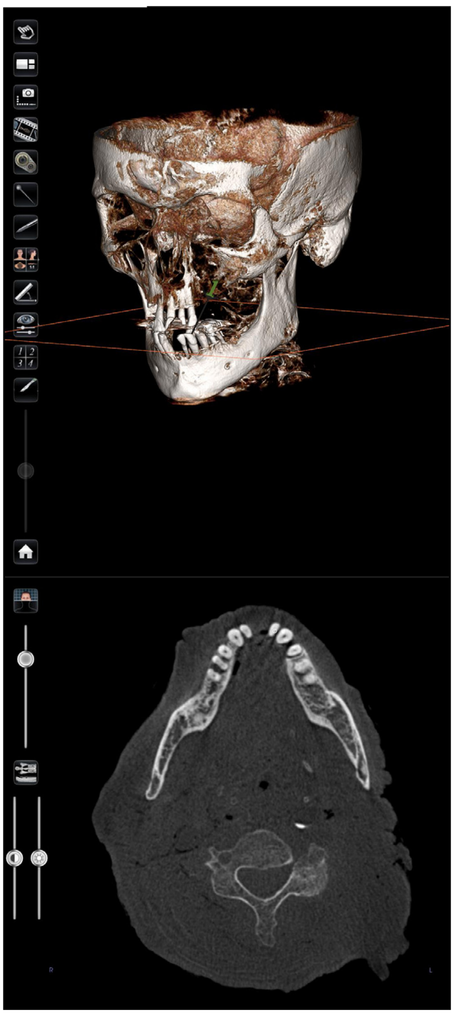

Fig. 7. Use of the *Anatomage* on a real dataset. High-resolution Cone-Beam images have been acquired, and the DICOM dataset has been loaded and rendered in 3D on the *Anatomage* table.