Article

Initial Stages of Development of an Automated Measurement Technique on Incisors

Armen Gaboutchian [1,*], Vladimir Knyaz [2,3], Sergey Vasilyev [4] and Anatoliy Maximov [3]

1 Peoples Friendship University of Russia, 117198 Moscow, Russia
2 State Research Institute of Aviation System (GosNIIAS), 125319 Moscow, Russia; kniaz.va@mipt.ru (V.K.)
3 Moscow Institute of Physics and Technology (MIPT), 141701 Dolgoprudny, Russia; max@gosniias.ru (A.M.)
4 Institute of Ethnology and Anthropology RAS, 119991 Moscow, Russia; vasbor1@yandex.ru (S.V.)

* Corresponding author. E-mail: armengaboutchian@mail.ru (A.G.)

Received: 7 April 2024; Accepted: 23 May 2024; Available online: 4 June 2024

ABSTRACT: Teeth are an important object of studies in many scientific disciplines and, among various study techniques, measurements have one of the most promising prospects for further improvements supported by progress in computer sciences, imaging and image processing. Our recent work on automated odontometric algorithms for premolars and molars has gradually come to develop similar methods for another group of teeth—incisors. Using 3D reconstructions of teeth obtained through micro-focus tomographic scanning, we propose landmarks, which correspond to main morphological features of incisors and enable their formal description. In this article we present an orientation and measurement technique, based on an interpretation of incisor morphology, as a system which is able to perform in a fully automated mode. Since the primary objective of the current paper is to introduce methodological improvements, data on measurements and their results are shown at the most basic level.

Keywords: Incisor; Automated digital odontometry; Orientation; Sunghir; Micro-computed tomography

1. Introduction

Teeth are one of the most important objects of research in anthropology, palaeontology and other human and natural studies. Various study techniques are used in dental research, amongst which are measurement techniques for analysing sizes and morphology of teeth [1,2]. Descriptive methods usually prevail, however, largely due to the wide morphological variance and different conditions of the studied teeth. Measurements often accompany descriptions of dental traits and scoring of their expression level in odontological studies, mainly with maximal mesio-distal and bucco-lingual diameters of tooth crowns being measured [3,4]. On worn teeth, measurements on cervices are seen as more informative [5,6]. Recent progress in computer sciences and imaging has stimulated the development of measurement methods and miscellaneous techniques [7–9]. However, many of those methods do not appear to be sufficiently systematised for direct combined application and correct comparison of obtained results [6]. Given the above circumstances, measurement automation can support the development of more versatile tools and facilitate cross-methodological collaboration.

During recent years, we have been developing automated digital odontometric techniques, advancing in two main directions. Firstly, we paid special attention to detecting associations between dental morphology and method framework by identifying landmarks on teeth and setting software running sequences, ensuring performance of an algorithm at all stages, from tooth model loading, through its surface analysis and orientation, to measurements. We proposed the said method framework as the software functioning and settings should be based on the most principal features of teeth, which could be reliably and correctly detected and depicted. Secondly, defining significant morphological structures provides the appropriate degree of flexibility of the automated technique for versatile and multi-task measurements [10,11], which is especially beneficial taking into consideration the diversity of morphological types in heterodont masticatory systems, biological variance of teeth and different conditions of studied material mainly influenced by dental wear. Of course, this technique, being digital, works with 3D reconstructions. Nevertheless, depending on study objectives and stages, both 2D and 3D modes can be used.

https://doi.org/10.35534/natanthropol.2024.10010

At early stages of the odontometric technique development optical scanning methods were used. They actually provide an acceptable quality of 3D models that meet the study requirements. However, at the current stage of research, high resolution x-ray tomographic imaging and reconstruction provides sufficient information on the required detail of dental morphology [12] satisfying the requirements of the majority of studies, unless special samples or aspects are studied [13]. Thus micro-focus computed tomographic scanning becomes more widely used in research today. Such studies are carried out on teeth classified into different groups, including incisors, which are of particular interest in this paper. We here focus on new methodological aspects of measuring incisors and present functioning of the automated digital technique at a basic level.

Odontometry on incisors can be carried out on different types of samples. Manual measurements are usually conducted on real teeth or their copies (e.g. when paleontological findings are studied [14]). Plaster models can also be used for manual measurements, for instance for analysing and classifying shapes of teeth [15]. At the same time, in some other, yet similar, phenotypic studies plaster models can be successfully substituted by digital images, which are arguably more convenient for marking and defining measurable variables [16]. Similar studies conducted on 3D reconstructions give wider opportunities for obtaining more diverse and objective data in convenient ways, taking into consideration conventional benefits of digital software application [17] and application of geometric morphometric analysis [18]. There are also examples of measurements of morphological traits on incisors, which include linear and angular geometric constructions on different morpho-histological layers of teeth [19]. Among other studies on incisors, those using multidisciplinary approaches, including calculations, sectioning, stress analysis and geometric morphometrics, can be mentioned [20,21]. Thus, studies of frontal teeth, including upper and lower incisors, are significant in dental research; hence development of new automated measurement techniques with advanced functionality could potentially be of value for odontology.

Methodological studies and comparisons of manual and digital measurements are very important [22], and hence digital techniques, including automated algorithms, can provide researchers with opportunities for further advances, beyond the limits of classical methods, in studying different teeth, including incisors, as presented in the paper. One of the most important stages in measurement systems is object orientation as this factor contributes to accurate measurements and enables comparison of obtained results. Edges of incisors can serve for orientation purposes [23], but these structures morphologically are very variable on different teeth—be they intact or worn. Taking into consideration the diversity of existing orientation systems [24], automated techniques can serve as an analytical tool and have a potential for orientating measured objects reliably.

Measurement errors are another typical topic of discussions in odontometric studies. While inter-observer and orientation errors can generally be comparable to intra-observer errors [25], automated algorithms have the advantage of decreasing the probability of errors, limiting differences in obtained measurement results to characteristics of scanning and reconstruction techniques or choices of settings of automated algorithms. Moreover, automated odontometric methods may be suitable for multi-task analysis, as 3D automated techniques, when combined with classical methods, expand their potential and serve, as an example, for the description of dental morphology, size of teeth or dental enamel thickness.

2. Materials and Methods

2.1. Materials

As has been mentioned, high resolution x-ray tomographic scanning enables clearer reconstruction of morphological structures, which have important roles to play in setting automated algorithms. For our study we used 3D reconstructions of incisors taken from the Sunghirian findings. This work mainly presents new expansions of automated measurement methods, rather than odontological analyses based on measurement results, hence we do not focus on archaeological and anthropological description of the well-known Upper Palaeolithic site and its former inhabitants. The original material is represented by skulls with dental arches, as teeth could not be extracted from the bone sockets (alveolae). Phoenix v|tome|x m (Waygate Technologies) was therefore used as an appropriate instrument for placing and scanning skull-size objects. The scanning of the Sunghirian S2 individual's skull was performed with the following settings: 275 kV voltage, 400 µA current at tube and 250 ms exposure time. The entire stack of scans was sorted to separate images referring to each tooth, which were subsequently processed on Avizo 9.01 (Thermo Fisher Scientific). Thresholding has allowed to segment the enamel layer due to the extraordinarily high absorption rate of the highest mineralised tissue in human bodies. The result of image processing was to obtain enamel cap reconstructions of upper right and lower left second incisors with isometric voxel side size of up to 43 µm. While choosing teeth for developing and testing the algorithms we did not select samples with close-to-ideal morphology, mainly for objectivity reasons. Both teeth have imperfections: while the upper incisor has an excess of enamel in the cervical area, the lower incisor is characterized by an exposed area of dentine at the mesial corner of its crown.

2.2. Methods

Having at our disposal a previously developed custom odontometric software (O3DO software, registration number RU 2019665315), which performs visualisation, surface curvature analysis, coordinate system setting, sectioning and other tasks, we defined one of the main problems of the study in correctly identifying incisor features to enable effective running of automated algorithms, since incisors have essential morphological differences compared with the earlier studied molars. In other words, it is important to find morphological features that would fit the image processing capability of the software. This condition is especially significant for orientation, which is, in fact, the basis of any measurement system and has a clear impact on measurement results. One of the most essential structures for orientation in all groups of teeth is the cervical margin of the enamel cap, which can be clearly visualised by means of high resolution scanning techniques. We use the centre of mass of the enamel cap cervical margin, which represents a closed line curved in three dimensions. Thus, its geometric centre serves as a tooth orienting coordinate system origin.

It might seem obvious from functional and morphological perspectives that the only prominent structure incisors possess is their edge, which should be incorporated in the development of orientation and measurement algorithm. Nevertheless, for setting the direction of the vertical y-axis we used an algorithm for identifying the corners of the enamel cap. The incisal edge was found inappropriate for formal description and clear detection due to its complex and variable morphological structure. The current version of vertical axis direction setting presents it as the bisector of the angle, whose sides are limited by lines running from the origin of the coordinate system to the crown corners. The plane, defined by three points—one centre of mass of the enamel cervical margin and two incisal edge corner points (mesial and distal)—sets the direction of the horizontal x-axis and the sagittal z-axis. The maximal mesio-distal crown diameter is measured between two other points, which are set by the initial contact of two virtual parallel planes with mesial and distal surfaces of enamel cap reconstructions of the incisors. These planes are perpendicular to the horizontal axis, and therefore the measured parameter, thus represents a projection of the distance between the two points onto the x-axis.

3. Results

The custom-developed software allows to perform the above-mentioned procedures automatically. The entire process from model uploading to obtaining measurement results actually takes less than 30 seconds, and the only manually operated procedure is the selection of the corresponding mode for incisors, which performs differently from modes developed earlier for molars, premolars and canines. Surface analysis, orientation, localisation of crown edge angles and measurements do not require any interference from the operator. An example of some basic measurements, representing the result of measuring the mesio-distal crown diameter of the two discussed above incisors is set out in Table 1. Insofar as the proposed algorithm works using two extreme lateral points of the incisal edge of the crown (marked in blue in Figures 1 and 2), we present the x-axis projection of the distance between these two points as a potentially measurable and automatically generated parameter. We name this parameter as interangular distance (Table 1), because the points, which define this parameter, are vertices of mesio-incisal and disto-incisal angles of the tooth crown.

Table 1. Parameters measured automatically on the incisors.

Incisor	Mesio-Distal Diameter, mm	Interangular Distance, mm
Upper right second	8.40	6.07
Lower left second	6.48	5.67

The genuine interface for measuring teeth looks exactly as presented in Figure 1. As can be seen, the coordinate system is presented as arrows of different colours; the blue points locate crown mesial and distal incisal angles; the MD-diameter measurement points are marked in green. The red-coloured area is the result of surface curvature analysis algorithm. Hereafter we shall present the results of this algorithm functioning to demonstrate the reasons for choosing the crown incisal edge angle points as landmarks reliably representing incisor morphology. As shown in Figure 2a,b, not all points found in the areas with corresponding curvature are located on the incisal edges, and not the entire area which would be considered as of the incisal edge, is marked correspondingly. Moreover, there is a considerable difference in the appearance of the incisal edge even between these two teeth, but, in fact, its natural variance is significantly wider.

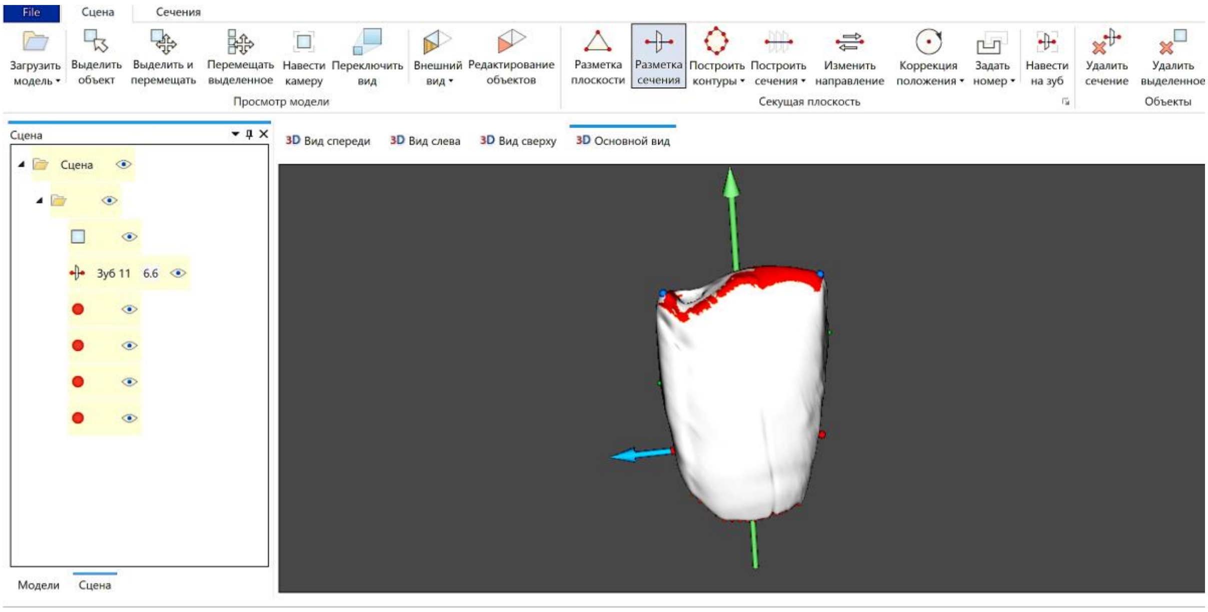
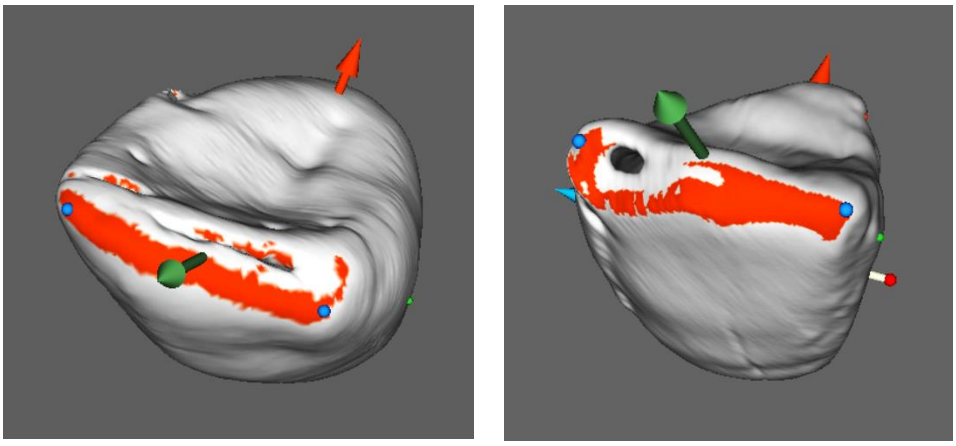


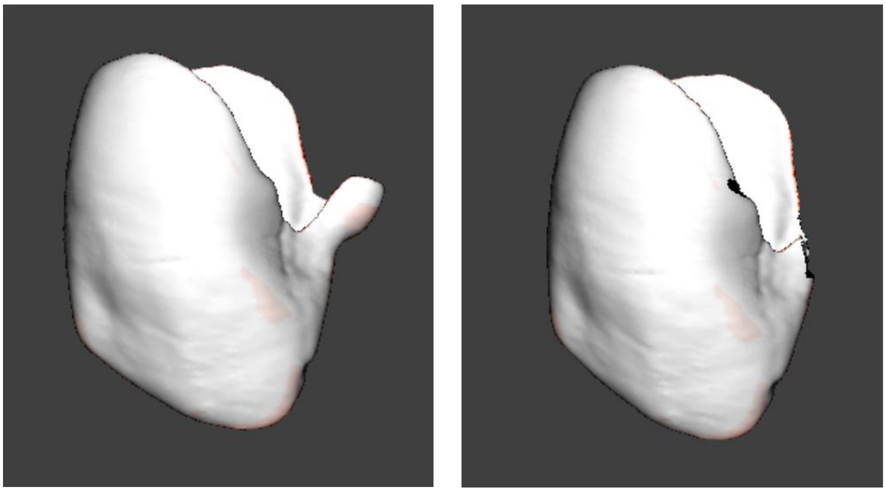
Figure 1. Lower left second incisor in the software interface; frontal view.



(**a**) (**b**)

Figure 2. Incisal view of upper (**a**—left) and lower (**b**—right) second incisors with areas of correspondence to the surface curvature setting, marked in red.

Following planned improvements to the automated algorithm, the presented results will likely be altered because of changes in orientation. Meanwhile, we trimmed the 3D reconstruction of the enamel cap of the upper incisor, which allowed the current software version to perform more effectively as it could not previously measure the MD crown diameter correctly with the unusual morphological extension of the upper second incisor enamel (Figure 3a,b).



(**a**) (**b**)

Figure 3. (**a**) and (**b**). Mesio-frontal view of the upper right second incisor before (left) and after (right) trimming the enamel extension.

4. Discussion

Measurement techniques are one of the most rapidly and extensively developing study methods in odontological research and can be instrumental in better understanding the morphological features of teeth. Automation provides multiple benefits for a measurement system (or systems), in many respects, including speed (results are obtained within seconds) and usability, which are already applicable, as well as a potential for providing compatibility of different methods. If compared with manual and semi-automated techniques, automated measurements do not depend upon subjective factors, except the choice of study material and some customisable settings (e.g. number of sections or sectioning mode, where applicable). This feature is very helpful for communication between researchers, as measurements can be accurately reproduced on the same model in an errorless manner and regardless of researchers' skills, time and place of research and other factors. An example of an automated algorithm is presented in Figure 4. That being said, any method, including automation, should rely on fundamentals of dental morphology and, at the same time, serve for the purpose of describing its features. As new extensions of automated techniques for incisors are proposed, we shall discuss some aspects, which can be found important for its correct understanding.

Algorithm 1: Tooth morhological analysis

Input:
tooth 3D model $\mathbf{T} = \{t_i\}$,
Output:
tooth odontometric parameters $\mathbf{P}_o = \{p_j\}$

Tooth 3D model $\mathbf{T}$ orienting into standard position ;
Procedure Orienting(T):
  for *each point t_i of tooth 3D model T* **do**
    Find Gaussian curvature $K_i = \kappa_1 \cdot \kappa_2$ at point t_i
    if $K_i > K_{treshold}$ **then**
      find normal to the tooth surface n_i at point t_i
      save t_i in occlusion surface border array O_b;
      save n_i in occlusion surface normals array O_b^n;
    else
      skip;
    Find occlusion surface border as a set of points with maximal curvature K ;
    Find tooth normal $\mathbf{n}_T$ as an average of occlusion surface normals n_i ;
  return O_b^n, $\mathbf{n}_T$;

Tooth sectioning and odontometric parameters determination ;
Procedure Slicing(O_b^n, T):
  Approximate O_b^n by an ellipse;
  Make N_s sections by planes normal to the major axis of the ellipse;
  for *each section S_k* **do**
    detect tooth landmarks ;
    determine a set of tooth odontometric parameters $\{p_o\}$;
    store tooth odontometric parameters $\{p_o\}$ for further statistical processing
  return $\{p_o\}$;

Figure 4. Algorithm for automated orientating and measuring teeth.

Special attention was paid to orientation of teeth, which is considered to be one of the most essential stages of any measurement technique. Taking into consideration the complexity of shapes of teeth and their variability, there are numerous methods of setting positions of teeth and instruments prior to measuring. Our own experience of developing an automated odontometric system for 3D reconstructions of teeth suggests that specific structures must be chosen that are relevant to the very basic features of dental morphology for orientation purposes. Such structures should be simplified to the minimal number of points and their coordinates for setting directions of axes, among which the vertical axis is paramount as it gives the most reliable lengthwise orientation. Thus, within the proposed technique just three points have been found to be sufficient for setting the vertical axis direction of an incisor. These three points should preferably be positioned at maximal distances from each other to improve correct setting of axis direction. The first point on all groups of teeth, including incisors, is the centre of mass of points representing the enamel cervical margin of the tooth crown on the 3D model. It is worth mentioning that these centroids can be used in odontological studies for marking tooth outlines in 2D mode [26]. Teeth acquire their enamel cervical at the end of the enamel formation process. Micro-computed tomography provides adequate reconstruction of this structure, but reconstruction quality still depends on many factors. The edge is thin, and therefore its reconstruction accuracy is rather contingent upon scanning resolution. For the same reason, while chipped edges are observed on palaeo-material, restoration should still be possible if traces of enamel edge are observed on the dentine layer. We can also speculate on the stability of the enamel edge, but it is presumably less prone to changes if compared with those surfaces, which are in contact with adjacent and opposing teeth. In addition, carious and non-carious lesions may cause morphological changes in the cervical enamel.

The enamel cervical margin is curved to various degrees on different teeth in heterodont systems. Incisors possess one of the most sinuous edges, hence trimming them is not recommended for orientation purposes. Coordinates of all points representing the enamel cervical margin are used for defining the position of the centre of mass of the enamel cervical margin as the origin of the tooth crown vertical axis. The other point of the vertical axis is set on the opposite part of the incisor crown—its incisal edge, which is responsible for function performance. Despite the wide use of incisal edges for orientating in visual analysis, it is difficult to describe the complete natural detail and features of these morphological structures by means of digital image analysis. This difficulty in describing the incisors' edge and its outline variance can turn the incisal edge into an object of research rather than a basic feature for orientation and interpretation of crown shape. Despite the fact that incisors undergo significant morphological changes as they wear, whilst preserving the ability to perform their function, their edges gradually turn into flattened facets, various in shapes, areas, inclinations or other features. Nevertheless, incisors and their incisal edges do not lose that morphological feature, which is used in the proposed measurement technique. This feature encompasses the two points of the incisal edge of the crown that are used for orientating the vertical axis and defining the frontal plane. These points can also serve as landmarks for limiting the borders of the incisal edge with mesial and distal surfaces.

5. Conclusions

Measurements on incisors can be carried out in a fully automated mode. The algorithms presented in this paper perform orientation and, for now, the most basic measurement, that is the mesio-distal crown diameter. The technique description includes a substantiation of morphological landmark choices on incisors and measurement procedures for the proposed method.

As the algorithm is still being developed, it is not yet in open access. We believe that joint testing and use of the measurement technique for scientific applications would be an important part of development, and hence we are open to prospective collaboration.

Going forward, our plans are to develop the following elements for our automated digital odontometric system for incisors: differentiation of measurements on upper and lower teeth, measurement on worn teeth, expansion of the measured parameters' range, as well as further improvements which would allow to avoid trimming procedures in cases of unusual incisor morphology.

Acknowledgments

We commend Dr. D.V. Korost from the Faculty of Geology of the Moscow State University and N.V. Stepanov for their assistance in micro-focus tomographic scanning and 3D reconstruction and S.N. Hajyan for his support in graphical design.

Author Contributions

Conceptualization, A.G. , V.K. and S.V.; Methodology, A.G., A.M.; Software, V.K., A.M.; Validation, S.V., V.K. and A.G.; Writing—Original Draft Preparation, A.G., A.M.; Writing—Review & Editing, A.G., V.K. and S.V.; Visualization, A.M.

Ethics Statement

Ethical review and approval were waived for this study, due to involving palaeoanthropological materials in this study.

Informed Consent Statement

Not applicable.

Funding

This research received no external funding.

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.

References

1. Xiao D, Bae C, Shen G, Delson E, Jin J, Webb N, et al. Metric and geometric morphometric analysis of new hominin fossils from Maba (Guangdong, China). *J. Human Evol.* **2014**, *74*, 1–20.
2. Margherita C, Talamo S, Wiltschke-Schrotta K, Senck S, Oxilia G, Sorrentino R, et al. A reassessment of the presumed Torrener Bärenhöhle's Paleolithic human tooth. *J. Human Evol.* **2016**, *93*, 120–125, doi:10.1016/j.jhevol.2016.01.007.
3. Bermúdez de Castro J-M, Martinón-Torres M, Martínez de Pinillos M, Garcia C, Modesto Mata M, Martín-Francés L, et al. Metric and morphological comparison between the Arago (France) and Atapuerca-Sima de los Huesos (Spain) dental samples, and the origin of Neanderthals. *Quat. Sci. Rev*. **2018**, 217, 1–17, doi: 10.1016/j.quascirev.2018.04.003.
4. Berger LR, Hawks J, Ruiter DJ, Churchill SE, Schmid P, Williams S, et al. A new species of Homo from the Dinaledi Chamber, South Africa. *eLIFE* **2015**, *4*, e09560.
5. Hillson S, Fitzgerald C, Flinn H. Alternative dental measurements: Proposals and relationships with other measurements. *Am. J. Phys. Anthropol.* **2005**, *126*, 413–426.
6. Benazzi S, Panetta D, Fornai C, Toussaint M, Gruppioni G, Hublin J-J. Technical Note: Guidelines for the Digital Computation of 2D and 3D Enamel Thickness in Hominoid Teeth. *Am. J. Phys. Anthropol*. **2014**, *153*, 305–313, doi:10.1002/ajpa.22421.
7. Guy F, Gouvard F, Boistel R, Euriat A, Lazzari V. Prospective in (Primate) Dental Analysis through Tooth 3D Topographical Quantification. *PLoS ONE* **2013**, *8*, e66142.
8. Choi G, Chan HL, Yong R, Ranjitkar S, Brook A, Townsend G, et al. Tooth morphometry using quasi-conformal theory. *arXiv* **2019**, 1901.01651v1 [cs.CV], (*Preprint submitted to Pattern Recognition*).
9. Zanolli C, Martinón-Torres M, Bernardini F, Boschian G, Coppa A, Dreossi D, et al. The Middle Pleistocene (MIS 12) human dental remains from Fontana Ranuccio (Latium) and Visogliano (Friuli-Venezia Giulia), Italy. A comparative high resolution endostructural assessment. *PLoS ONE* **2018**, *13*, e0189773.
10. Gaboutchian AV, Knyaz VA, Korost DV. New Approach to Dental Morphometric Research Based on 3D Imaging Techniques. *J. Imag*. **2021**, *7*, 184.
11. Gaboutchian AV, Knyaz VA, Maschenko EN, Dac LX, Maksimov AA, Emelyanov AV, et al. Measuring Dental Enamel Thickness: Morphological and Functional Relevance of Topographic Mapping. *J. Imag*. **2023**, *9*, 127.
12. Maret D, Peters O, Galibourg A, Dumoncel J, Esclassan R, Kahn J-L, et al. Comparison of the Accuracy of 3-dimensional Cone-Beam Computed Tomography and Micro–Computed Tomography Reconstructions by Using Different Voxel Sizes. *J. Endod*. **2014**, *40*, 1321–1326, doi:10.1016/j.joen.2014.04.014.
13. Zanolli C, Schillinger B, Kullmer O, Schrenk F, Kelley J, Rössner G, et al. When X-Rays Do Not Work. Characterizing the Internal Structure of Fossil Hominid Dentognathic Remains Using High-Resolution Neutron Microtomographic Imaging. *Fron. Ecol. Evol*. **2020**, *8*, doi:10.3389/fevo.2020.00042.
14. Xing S, Martinón-Torres M, Castro J, Zhang Y, Fan X, Zheng L, et al. Middle Pleistocene Hominin Teeth from Longtan Cave, Hexian, China. *PLoS ONE* **2014**, *9*, e114265.
15. Song J-W, Leesungbok R, Park S-J, Chang S, Ahn S-J, Lee S-W. Analysis of crown size and morphology, and gingival shape in the maxillary anterior dentition in Korean young adults. *J. Adv. Prosthodont*. **2017**, *9*, 315.
16. Khalaf K, Smith R, Elcock C, Brook A. Multiple crown variables of the upper incisors in patients with supernumerary teeth compared with controls. *Arch. Oral Biol.* **2009**, *54*, S71–S78.
17. Smith R, Zaitoun H, Coxon T, Karmo M, Kaur G, Townsend G, et al. Defining new dental phenotypes using 3-Dimage analysis to enhance discrimination and insights into biological processes. *Arch. Oral Biol*. **2009**, *54S*, S118–S125.
18. Wang H, Yin J, Lu P, Yu Q. Three-dimensional geometric morphometric measurement and classification of maxillary central incisors. *Arch. Oral Biol*. **2019**, *102*, 141–146.
19. Denton L. Shovel-shaped incisors and the morphology of the enamel-dentin junction: An analysis of human upper incisors in three dimensions. Master Thesis, Colorado State University, Fort Collins, CO, USA, 2011.
20. Carayon D, Adhikari K, Monsarrat P, Dumoncel J, Braga J, Duployer B, et al. A geometric morphometric approach to the study of variation of shovel-shaped incisors. *Am. J. Phys. Anthropol*. **2018**, *168*, 1–13. doi:10.1002/ajpa.23709.
21. Najafzadeh A, Hernaiz-García M, Benazzi S, Chen B, Hublin J-J, Kullmer O, et al. Finite element analysis of Neanderthal and early Homo sapiens maxillary central incisor. *J. Human Evol.* **2024**, *189*, 103512.
22. Naidu D, Freer T. The evidence supporting methods of tooth width measurement: Part I. Vernier calipers to stereophotogrammetry. *Aust. Orthod. J*. **2013**, *29*, 159–163.
23. Smith T, Olejniczak A, Zermeno J, Tafforeau P, Skinner M, Hoffmann A, et al. Variation in enamel thickness within the genus Homo. *J. Human Evol*. **2012**, *62*, 395–411.
24. Benazzi S, Fantini M, De Crescenzio F, Persiani F, Gruppioni G. Improving the spatial orientation of human teeth using a virtual 3D approach. *J. Human Evol*. **2008**, *56*, 286–293.

25. Bailey S, Benazzi S, Buti L, Hublin J-J. Allometry, Merism, and Tooth Shape of the Lower Second Deciduous Molar and First Permanent Molar. *Am. J. Phys. Anthropol*. **2016**, *159*, 93–105, doi:10.1002/ajpa.22842
26. Benazzi S, Fornai C, Buti L, Toussaint M, Mallegni F, Ricci S, Gruppioni G, Weber G, Condemi S, Ronchitelli A. Cervical and Crown Outline Analysis of Worn Neanderthal and Modern Human Lower Second Deciduous Molars. *Am. J. Phys. Anthropol*. **2012**, *149*, 537–546, doi:10.1002/ajpa.22155.