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ABSENCE OF FORAMEN SPINOSUM AND ABNORMAL MIDDLE MENINGEAL ARTERY IN CRANIAL SERIES

S. Nikolova, D. Toneva, Y. Yordanov, N. Lazarov

In comparative and evolutionary aspects in humans, the middle meningeal artery enters the cranium through the foramen spinosum, whereas in great apes the middle meningeal artery can enter the cranium through foramen spinosum, through foramen ovale or through petrosphenoid fissure. Generally, in nonhuman primates the anterior meningeal system is associated with the ophthalmic branch of the internal carotid artery. The vessels joining the two systems pass through the additional channels: the superior orbital fissure or through the cranio-orbital foramen.

In anatomically modern humans, the absence of foramen spinosum involves abnormal development and course of the middle meningeal artery and it is usually accompanied with replacement of the conventional middle meningeal artery with such, arising from the ophthalmic artery system. In these cases the middle meningeal artery most often enters the middle cranial fossa through the superior orbital fissure and rarely through the meningo-orbital foramen.

All skulls, investigated in the present study, belonged to adult individuals of both sexes, conditionally grouped into three cranial series – contemporary male, medieval male, and medieval female series. The absence of foramen spinosum was established only among the medieval male and female series – in 1 (0.70 %) male and in 1 (0.72 %) female skull on the right side and in 3 (2.13 %) female skulls on the left side. In 1 (0.72 %) female skull, a small atypically located foramen spinosum was established on the right side. In all of the described cases, the intracranial meningeal grooves started from the lateral edge of the superior orbital fissure and probably reflect the ophthalmic origin of the middle meningeal artery.

Key words: foramen spinosum absence, meningo-orbital foramen, middle meningeal artery, ophthalmic artery, stapedial artery

VARIATIONS IN THE SQUAMOUS PART OF THE OCCIPITAL BONE IN MEDIEVAL AND CONTEMPORARY CRANIAL SERIES FROM BULGARIA

S. Nikolova, D. Toneva, Y. Yordanov, N. Lazarov

The squamous part of the occipital bone is a place of many different variations. They are a result of faulty ossification in the occipital squama or due to the presence of sutural bones in the lambda region. As their differentiation is intricate because of the various criteria used, the issue of their recognition in the adult skull still remains difficult even though they can be clearly distinguished at a younger age. The aim of the present study was to compare the frequency of interparietal, preinterparietal and sutural bones in the lambda region in medieval male and female cranial series as well as between medieval and contemporary male series from Bulgaria. We also discuss the development of the occipital squama in order to set clearer criteria for further differentiation of such variations in the adult skull. In the reviewed 3 cranial series, the variations in the squamous portion of the occipital bone were observed with a low frequency. The incidence of preinterparietal bones was more common than the interparietal ones. The sutural bones in the lambda region were numerous in the series. No statistically significant sex or intergroup differences were established. So even if these anatomical variations are relatively rare, the understanding of them is of significance for many disciplines like anthropology, comparative and developmental anatomy, clinical and forensic medicine. (Folia Morphol 2014; 73, 4: 429–438)

Key words: interparietal bone, preinterparietal bone, sutural bones

MULTIPLE WORMIAN BONES AND THEIR RELATION WITH DEFINITE PATHOLOGICAL CONDITIONS IN A CASE OF AN ADULT CRANIUM

S. Nikolova, D. Toneva, Y. Yordanov, N. Lazarov

Wormian bones, also known as intrasutural bones, are present as an anatomical variation in healthy individuals. However, a higher than the usual incidence can be an important feature of some congenital pathological conditions. In this study we describe a case of an adult cranium with multiple Wormian bones. The cranium was a single sample obtained from an archaeological excavation in Vinitsa, Northeastern Bulgaria, and probably dated in the Chalcolithic. The Chalcolithic is a period of human history connected with discovering and using of copper. Actually, it is a transitional phase between the Neolithic and the Bronze Age. In this case the Wormian bones are mostly large in size and arranged in a mosaic pattern in several cranial regions. The cranium also shows features such as dolichocrany, a moderate platybasia, a notch in the posterior margin of the foramen magnum, hypoplastic and asymmetrical frontal sinuses, underdeveloped mastoid air cells, hyperostosis cranii interna, moderate frontal bossing, a complete metopic suture, a delayed sutural closure, relatively small facial bones, an early loss of teeth, dental caries and hypoplastic enamel defects on two preserved molars. Differential diagnosis indicates that the combination of all these features shows a link with pathological conditions involving dysplasias with prominent membranous bone involvement and an increased bone density such as cleidocranial dysplasia and pyknodysostosis.

Key words: paleopathological differential diagnosis, cleidocranial dysplasia, pyknodysostosis, intrasutural bones

TWO CASES OF LARGE BREGMATIC BONE ALONG WITH A PERSISTENT METOPIC SUTURE FROM NECROPOLES ON THE NORTHERN BLACK SEA COAST OF BULGARIA

S. Nikolova, D. Toneva, I. Georgiev, Y. Yordanov, N. Lazarov

The co-occurrence of a bregmatic bone and metopism is an extremely rare finding. In the present study we investigate, compare, and describe this uncommon combination in two skulls of a child and an adult male. Both samples were from the osteological collection of the Institute of Experimental Morphology, Pathology and Anthropology with Museum, Bulgarian Academy of Sciences. The skulls were obtained from archaeological excavations of two necropoles located on the northern Black Sea coast of Bulgaria. The samples were macroscopically observed and measured. A CT scan was also performed in order to investigate the internal structure and the relation between the calvarial bones. Both bregmatic bones were slightly prominent unpaired structures wedged into the frontal and parietal bones with a developed diploic space. In the child, the frontal sinus was underdeveloped, whereas in the adult the frontal sinuses were well developed on both sides of the metopic suture. In the latter, an osteoma on the left side of the sinus was observed. The retention of the metopic suture along with the formation of a bregmatic bone could be considered as indispensable accessory sites for the regulation of the bone growth as a response to the increasing brain mass requirements under specific circumstances. This could be a mechanism for maintaining the optimal balance between the calvarial shape and size for a maximal effectiveness and stability in the presence of some developmental abnormalities.
Key words: wormian bones, bregmatic bone, persistent metopic suture, CT-imaging

INCIDENCE OF A BIFID MANDIBULAR CONDYLE IN DRY MANDIBLES

S. Nikolova, D. Toneva, N. Lazarov

Background: A bifid mandibular condyle (BMC) is a rare anatomical variation with an etiology not fully understood. Although there are numerous case reports regarding it, purposeful epidemiological investigations on the BMC frequency among different groups are scarce. This study aims to investigate the incidence and laterality of BMC among series of adult males from Bulgaria and perform a morphometric analysis of it.

Materials and methods: A series of 500 dry intact mandibles from adult males was investigated. The condyles were macroscopically observed and when skulls were available, the corresponding mandibular fossae were also inspected. In the cases when bifid condyles were found, 27 measurements were taken.

Results: Bifid mandibular condyle was observed in 4 (0.8%) mandibles. All of the cases were unilateral, 2 on the right side (0.4%) and 2 on the left (0.4%). The condyles were divided into medial and lateral heads by a sagittal fissure or a notch.

Conclusion: The established frequency of BMC was comparable with those reported in Turkish and Korean populations. The lack of injury marks and traces implies a developmental etiology of this condition.

Key words: Bifid mandibular condyle, dry mandible, mandibular fossa

MORPHOMETRIC STUDY OF THE MYLOHYOID BRIDGING IN DRY MANDIBLES

S. Nikolova, D. Toneva, Y. Yordanov, N. Lazarov

The mylohyoid bridging is a hyperostotic variation representing formation of bony bridges over the mylohyoid groove. The goals of this study were to establish the frequency of mylohyoid bridging in contemporary and medieval series from Bulgaria and to examine the changes in the prevalence through time, to assess and compare the different types of mylohyoid bridging, to establish the patterns of distribution with respect to laterality, sex and age and to accomplish a morphometric analysis. Materials and methods: The study was performed on a total of 448 intact dry mandibles of adult individuals from both sexes, grouped into contemporary male, medieval male and medieval female series from Bulgaria. The individuals in the series were distributed into two age cohorts: between 20–40 years old and above 40 years. Macroscopic, metric and statistical analyses were performed. Results and Conclusions: The frequency of the mylohyoid bridging was 10.99% (21 out of 191 mandibles) for the contemporary male series, 9.45% (12 out of 127) for the male series and 7.69% (10 out of 130) for the medieval female series. The comparison between both male series indicated slightly increasing of the mylohyoid bridging with time. No significant bilateral and sex differences in the frequency and pattern of distribution of the mylohyoid bridging were established. The most common type of bridging was the distal one. The dependence of the mylohyoid bridging on the aging is controversial since in the female series its frequency was significantly higher in the individuals over 40 years, while in both male series it did not differ considerably between the age groups. The metric analysis did not show significant differences between the male series. However, the sexual differences were noteworthy with respect to the whole length of the mylohyoid groove and the distance between the bridge and the distal point of the mylohyoid groove. Furthermore, the considerable differences between the metric characteristics of lingular and distal type showed that this approach is useful and could be applied for precise differentiation of the mylohyoid bridging types. During the investigation, we also observed several cases of an accessory groove in the region of the mylohyoid groove. This additional groove most probably reflects variations in the branching patterns of the inferior alveolar nerve and/or mylohyoid nerve and could be of importance in oral surgery and dental practice.

Keywords: mylohyoid bridging; lingular mylohyoid bridge; distal mylohyoid bridge; mylohyoid groove; dry mandible

A CT-STUDY OF THE CRANIAL SUTURE MORPHOLOGY AND ITS REORGANIZATION DURING THE OBLITERATION

S. Nikolova, D. Toneva, I. Georgiev, S. Harizanov, D. Zlatareva, V. Hadjidekov, N. Lazarov

Obliteration of the cranial sutures is an age-dependent process. Its premature occurrence (craniosynostosis) causes different craniofacial deformations, dependent on the affected suture(s). The understanding of the suture morphology and the remodeling processes during the obliteration is essential for early diagnosis and treatment of the premature closure. This study aimed to investigate the morphology of open and obliterated sutures and to perform comparison analysis on the 3D images obtained by both industrial and chemical computed tomography (CT) systems with various resolutions. A segment of the sagittal suture of dry skulls of known age and sex was scanned using Nikon XTH 225, an industrial CT system, developed by Nikon Metrology. The same section of the sagittal suture was observed on patients undergoing CT scanning with a multislice system Toshiba Aquilion 64 with 0.5 mm slice thickness. For 3D visualization, VGStudioMax 2.2 software was used. The suture morphology was observed in coronal section on sequential 2D slices. Micro-CT (μCT) scanning of dry skulls enabled calculation of the morphometric parameters and visualization of the microarchitecture of the suture and its reorganization during the obliteration, unlike the CT imaging of patients, where the sutures were scarcely discernable. In the entirely open sections of the suture the bone edges were separated by a gap of various widths. As the obliteration proceeded, the gap gradually reduced and the bone edges got into a contact. In the final stages, the traces from the contact faded away and the sutural area became a homogenous structure of increased integrity. The μCT scanning of dry bones is a powerful non-destructive technique for examination of the suture morphology. Remodeling of the suture during the obliteration leads to gradually diminishing of the gap between the bone edges to their entire coalescence.

Key words: dry skull, suture microarchitecture, obliteration, μCT scanning, clinical CT imaging

RELATION BETWEEN METOPIC SUTURE PERSISTENCE AND FRONTAL SINUS DEVELOPMENT.

S. Nikolova, D. Toneva, I. Georgiev, N. Lazarov

The frontal bone develops as two halves, which further unite in a single bone by the closure of the mid-sagittal metopic suture, typically by the end of the first postnatal year. The frontal sinus begins to expand into the orbital and vertical plates of the frontal bone postnatally and reaches the level of the nasion by the fourth year of age. At this time, the metopic suture is usually entirely closed. However, in the cases of failed closure of the metopic suture, its relationship to the frontal sinus development is still obscure. Here, we review the relevant literature and discuss the frontal bone development and maturation, from the viewpoint of the frontal sinus pneumatization in relation to the metopic craniosynostosis and failed closure of the metopic suture. The peculiar to the metopic skulls frontal bone configuration is rather an expression of the underlying neural mass demands than a consequence of the metopic suture persistence. Furthermore, the persistent metopic suture is frequently associated with a frontal sinus underdevelopment. It seems that the metopic suture does not inhibit the frontal sinus pneumatization itself, but rather both traits are an expression or an aftereffect of a certain condition during the early development.

Keywords: frontal bone, frontal sinus, persistent metopic suture, *metopism*, metopic craniosynostosis

MORPHOMETRIC ANALYSIS OF THE FRONTAL SINUS: APPLICATION OF INDUSTRIAL DIGITAL RADIOGRAPHY AND VIRTUAL ENDOCAST

S. Nikolova, D. Toneva, I. Georgiev, A. Dandov, N. Lazarov

Background: The morphology and dimensions of the frontal sinus (FS) are significant in the forensic, surgical and population context.

Purpose: The study aimed to compare linear FS measurements taken both on radiographs and virtual endocasts and to assess the impact of the skull angulation on the FS dimensions.

Material and Methods: Thirteen intact dry skulls of contemporary adult males were radiographed using industrial digital radiography while they were inclined in the Frankfurt plane, through the Caldwell's view up to the Water's view by angular steps of 5°. The width and height of both frontal lobes were measured in each projection. To verify the measurements on the radiographs, ten of the skulls were µCT-scanned and virtual endocasts of the FS were generated.

Results: The concordance between the measurements on the virtual endocasts and the radiographs in the Caldwell's view showed almost perfect concurrence for the width (0.998) and height on the left side (0.990), and substantial one for the height on the right side (0.961). Since the width is more sensitive compared to the height, any inclination from the initial position at the Caldwell's view caused a significant distortion of the FS measurements.

Conclusion: The industrial µCT-systems support both 2D and 3D imaging and could generate images with a high resolution. Therefore, if the industrial digital radiography is selected as an eligible imaging modality for FS investigation and documentation in conformity with the research goals, the appropriate skull positioning ensures reliable readings of the linear FS dimensions.

Keywords: frontal sinus; industrial digital radiography; digital radiomorphometry; µCT-imaging; virtual endocast; dry skull

SQUAMOUS SUTURE OBLITERATION: FREQUENCY AND INVESTIGATION OF THE ASSOCIATED SKULL MORPHOLOGY

S. Nikolova, D. Toneva, N. Lazarov

This study aimed to investigate the frequency of squamous suture (SqS) obliteration, to estimate the involvement of the major calvarial sutures and those surrounding the temporal squama, and to inspect the neuro- and basicranium for deformities. A series of 211 dry skulls of contemporary adult males were macroscopically observed. The skulls with closed SqS were scanned using an industrial μCT system. Digital morphometry of the skulls with obliterated SqS was performed by recording the 3D coordinates of anatomic landmarks and calculation of linear distances, angles and indices. Obliteration of SqS was observed in 3 (1.42%) skulls. One skull showed bilateral SqS obliteration. The other two cases were unilateral, one right-sided and one left-sided. SqS obliteration seems to be co-ordinated with the closure of the parietomastoid suture, partially related to the closure of the occipitomastoid, sphenoparietal and sphenofrontal sutures, and independent from the closure of the sphenosquamosal suture and the major calvarial sutures. No severe disproportions in the skull configuration were observed in the three investigated cases. The major differences in the complimentary hemicrania concern the parietal and occipital parts of the skull vault. Dorsum sellae erosion, an indicator for raised intracranial pressure, was observed in all three cases.

Keywords: Cranial suture biology · Squamous suture · Industrial μCT imaging · Craniosynostosis · Skull morphology

RELIABILITY OF SAGITTAL SUTURE MATURATION FOR AGE-AT-DEATH PREDICTION ASSESSED BY MEANS OF MACHINE LEARNING TECHNIQUES

S. Nikolova, D. Toneva, G. Agre

Objectives: The sagittal suture (SS) is one of the major calvarial sutures and is used as an age-at-death indicator in forensic and bioarchaeological expertise. This study aimed to investigate whether the degree of SS closure could be used for a reliable age-at-death prediction. For this purpose we investigated the degree of SS closure in depth and applied symbolic and sub-symbolic machine learning algorithms designed to solve regression tasks. **Materials and methods**: The SS was investigated in 88 dry adult male skulls of known age-at-death ranging between 20 and 58 years. The skulls were scanned using a μCT system. The SS closure degree was assessed on crosssectional tomograms along the suture length using a scoring scale based on the morphological reorganization during SS maturation in each of the 3 bone layers. The obtained data were organized into six training datasets containing the same set of examples but described by different sets of attributes. Linear regression and K-nearest neighbors algorithms were applied to learn age-at-death predictive models. **Results**: The learnt models which showed the best predictive age-at-death ability were those constructed on the training dataset for the SS closure degree at the external table by means of 15-nearest neighbors (RMSE = 6.2856) and linear regression (RMSE = 6.2880) algorithms. **Conclusion**: The best age-at-death predictive models have been learnt from the dataset in which the examples are described only by the external table closure degree along the SS length. The use of other attributes worsens the predictive ability of the learnt models.

MORPHOLOGY OF SUPRASCAPULAR NOTCH IN MEDIEVAL SKELETONS FROM BULGARIA

D. Toneva, **S. Nikolova**

The suprascapular notch is situated in the lateral part of the superior border of the scapula, just medial to the base of the coracoid process, giving passage for the suprascapular nerve. The aim of this study is to determine the frequency of different types of suprascapular notch in male and female medieval skeletal series and to assess the sexual differences. The shape of the notch was classified into 5 types, based on the scheme given by Alekseev. A total of 102 scapulae and scapular fragments were investigated. The results show that the deep notch was the most common. In the left female scapulae the shallow notch was frequently observed as well. Three cases of suprascapular foramen, which is considered as a risk factor for suprascapular nerve neuropathy, were observed and there was a double foramen in one of them, which is a very rare case. According to the results of $\chi 2$ test, there were no significant sexual differences in the distribution of notch types. Our results illustrate that there were some individuals among the investigated medieval population potentially affected by suprascapular nerve entrapment syndrome and their way of living may have been impacted by the symptoms accompanying this condition.

Key words: suprascapular nerve, suprascapular foramen, suprascapular nerve entrapment, superior transverse suprascapular ligament

ACCURACY OF LINEAR CRANIOMETRIC MEASUREMENTS OBTAINED FROM LASER SCANNING CREATED 3D MODELS OF DRY SKULLS

D. Toneva, **S. Nikolova,** I. Georgiev, A. Tchorbadjieff

The aim of this study was to establish the reliability of directly taken linear measurements on dry skulls and corresponding measurements taken on the 3D digital models created by laser scanning as well as to assess the agreement between both measuring methods. Four skulls were measured in two competitive methods—a direct measuring, based on the conventional craniometric method, and a digital measuring, accomplished on 3D models created by laser scanning. Thirteen cranial measurements were taken on both dry skulls and 3D models. The intra- and inter-examiner reliability was estimated using intraclass correlation coefficient. The agreement between both measuring methods was assessed applying the Bland-Altman method for replicated measurements. A Bland-Altman plot was constructed for each of the 13 parameters. The 3D model and directly taken measurements were assessed as highly reliable and reproducible, excepting the orbital height. Our results showed that 96 % of all digital measurements differ from the directly taken ones with less than 2 mm and respectively 67.6 % differ with less than 1 mm. Based on the results of the Bland-Altman plots, most of the measurements obtained by both measuring methods could be accepted as comparable, since the majority of differences were within the constructed limits of agreement. However, there were digital measurements, particularly these with landmarks situated on bone margins, which systematically overestimated the directly taken ones.

*Keywords***:** Laser scanning · Craniometry · 3D models · Accuracy · Reliability

FACIAL SOFT TISSUE THICKNESSES IN BULGARIAN ADULTS: RELATION TO SEX, BODY MASS INDEX AND BILATERAL ASYMMETRY

D. Toneva, **S. Nikolova**, I. Georgiev, S. Harizanov, D. Zlatareva, V. Hadjidekov, N. Lazarov

Background: The aim of the study is to measure the facial soft tissue thicknesses (STTs) in Bulgarians, to evaluate the relation of the STTs to the nutritional status, sex and bilateral asymmetry, and to examine the correlations between the separate STTs as well as between the STTs and body weight, height, and body mass index (BMI). In the present study, the facial STTs were measured on computed tomography scans of the head of Bulgarian adults.
Materials and methods: The STTs were measured at 7 midline and 9 bilateral landmarks. The measurements were performed in the free software InVesalius in the axial and sagittal planes. The mean, standard deviation, minimum and maximum values, median and coefficient of variation were reported for the STT at each landmark according to the sex and BMI category. The BMI, sex and bilateral differences were assessed for statistical significance. Pearson correlation analysis was applied to assess the strength and direction of the relationships between the STTs and body height, weight and BMI, as well as between separate STTs.
Results and Conclusions: The facial soft tissues in Bulgarian adults changed in accordance with the nutritional status of the individual and in both sexes all STTs augmented with the increasing BMI. For both normal and overweight BMI categories, males had more soft tissue at the majority of facial points than females, as the only exceptions were observed in the cheek zone, where STTs were thicker in females. Significant bilateral differences were observed in either sex and BMI category. Stronger correlations were established for the STTs in the jaw region and between the cheek and jaw soft tissues. Besides, the correlations between the homologous bilateral landmarks were among the strongest ones. (Folia Morphol 2018; 77, 3: 570–582).
Key words: soft tissue thickness, computed tomography, sex, body mass index, bilateral asymmetry, Bulgarian adults, facial approximation

SEX ESTIMATION BY SIZE AND SHAPE OF FORAMEN MAGNUM BASED ON CT IMAGING

D. Toneva, **S. Nikolova**, S. Harizanov, I. Georgiev, D. Zlatareva, V. Hadjidekov, A. Dandov, N. Lazarov

Foramen magnum (FM) has a well-protected position, which makes it of particular interest in forensic research. The aim of the study is to assess the sex differences in size and shape of FM, develop discriminant functions and logistic regression models based on the FM measurements, compare the accuracy results of the measurements obtained through different measuring approaches, and establish the most reliable variables for sex estimation in Bulgarian adults. Head CT scans of 140 Bulgarian adults were used in the study. The segmentation of the skulls was performed in the software InVesalius. The length, breadth, circumference, and area were measured based on the 3D coordinates of definite landmarks and semi-landmarks. The circumference and area were calculated regarding the foramen as a 2D and 3D structure. Two additional variables (λ_2 and λ_3) corresponding to the least square errors along the length and breadth directions at the fitting of the 3D coordinates to a plane were examined for their sex discriminating ability. The FM shape was classified based on the values of the FM index. The significance of the sex differences was assessed. Discriminate function analysis and binary logistic regression were conducted. Significant sex differences were established in the FM size and shape. The eigenvalue λ_3 is the best discriminating parameter applying discriminant function analysis. The acceptance of FM as a 2D or 3D structure does not provide substantial information for its sex discrimination. The measurements of FM do not offer sufficiently high predicting rates for sex estimation in the Bulgarian population.

Keywords: foramen magnum, sex estimation, CT imaging, discriminant function analysis, binary logistic regression

SEX ESTIMATION BY MASTOID TRIANGLE USING 3D MODELS

D. Toneva, **S. Nikolova**, D. Zlatareva, V. Hadjidekov, N. Lazarov

Mastoid Triangle (MT) is a triangle constructed between the landmarks porion, mastoidale and asterion. The aim of the study is to evaluate the sex differences in the MT size in Bulgarian adults and to develop discriminant functions for sex estimation based on the MT sides and area. The study was carried out on 148 head CT scans. A sample of 53 males and 53 females was used for development of discriminant functions, and a test sample of 21 males and 21 females was applied for their validation. Using the software InVesalius©, 3D models of the skulls were segmented and exported in STL format. The 3D coordinates of the landmarks porion, asterion and mastoidale were collected using the software MeshLab©. The MT sides, area and angles were calculated. The sex differences were assessed by the independent t-test. Bilateral differences were evaluated using the paired t-test. Univariate and multivariate discriminant function analyses were applied. The results showed that the MT sides and area differed significantly between both sexes. Sex differences were also established for the angle at mastoidale. Bilateral differences were found in males for the distance porion-mastoidale, which was significantly greater on the right side. The MT dimensions showed sufficient discriminating power for sex estimation among Bulgarians (up to 89%), and the total MT area proved to be the best single sex discriminating trait. The test sample corroborated the usefulness of the MT in sex estimation demonstrating similar or higher overall accuracy rates.

*Keywords***:** mastoid triangle; sex differences; area; Bulgarians; discriminant functions

INVESTIGATION OF AN ORBITAL DEFECT IN A MEDIEVAL SKULL FROM BULGARIA

D. Toneva, **S. Nikolova**, I. Georgiev, N. Lazarov

In this study, we describe a defect of the right orbit, which affects the lateral surface and part of the orbital apex. The defect was observed on a skull from the medieval town of Kabyle, Southeastern Bulgaria (12th - 14th century). The skull belonged to a female at the beginning of adulthood (20-25 years). The orbital defect was observed macroscopically and via industrial μCT imaging. It represents an excision with a semilunar shape of the orbital surface in the greater wing of sphenoid bone. The margin of the excised part is relatively smooth with oblique inclination. The most probable causes this orbital defect could be an orbitocranial trauma or orbital trepanation due to some orbital pathological condition.

Keywords: orbitocranial trauma; orbital trepanation; orbital apex; medieval; μCT imaging

IMPACT OF RESOLUTION AND TEXTURE OF LASER SCANNING GENERATED THREE-DIMENSIONAL MODELS ON LANDMARK IDENTIFICATION

D. Toneva, S. Nikolova, I. Georgiev, N. Lazarov

The aim of the study was to determine the impact of the resolution and texture of three-dimensional (3D) models created through laser scanning on the measurement error (ME) of craniometric landmarks. Ten skulls were scanned at five different resolutions, and the generated 3D models were exported with and without texture. The 3D coordinates of 28 landmarks were derived. Each landmark was picked five times by one observer. The ME of a definite landmark was calculated as an average of distances between the repeated placements of the landmark by the observer and the landmark centroid. One-way analysis of variance was applied for detection of significant differences in the MEs between and within landmark types recorded at different resolutions. The MEs of landmark types in textured and nontextured models were compared by a paired test. Twelve linear measurements were calculated as interlandmark distances, and their values obtained on the models of different resolution were compared. The Frankfurt horizontal plane was constructed for each model and its deviation was calculated at different resolutions. Scan resolution impacted MEs of Type 1 and Type 2 landmarks but not the precision level of Type 3 landmarks. Texture most influenced the precise identification of Type 1 landmarks. The interlandmark distances between Type 2 landmarks were most consistent in their values, those between Type 1 landmarks showed deviations in low-resolution models, and distances between Type 3 landmarks demonstrated various patterns of transition of the values throughout the resolutions. Altogether, the use of textured high-resolution models would be preferable in morphometric studies.

Keywords: laser scanning; 3D model; resolution; texture; craniometric landmarks; measurement error

DATA MINING FOR SEX ESTIMATION BASED ON CRANIAL MEASUREMENTS

D. Toneva, **S. Nikolova**, G. Agre, D. Zlatareva, V. Hadjidekov, N. Lazarov

The aim of the present study is to develop effective and understandable classification models for sex estimation and to identify the most dimorphic linear measurements in adult crania by means of data mining techniques. Furthermore, machine learning models and models developed through logistic regression analysis are compared in terms of performance. Computed tomography scans of 393 adult individuals were used in the study. A landmark-based approach was applied to collect the metric data. The three-dimensional coordinates of 47 landmarks were acquired and used for calculation of linear measurements. Two datasets of cranial measurements were assembled, including 37 standard measurements and 1081 interlandmark distances, respectively. Three data mining algorithms were applied: the rule induction algorithms JRIP and Ridor, and the decision tree algorithm J48. Two advanced attribute selection methods (Weka BestFirst and Weka GeneticSearch) were also used. The best accuracy result (91.9 %) was achieved by a set of rules learnt by the JRIP algorithm from the dataset constructed by application of the GeneticSearch selection algorithm to the dataset of standard cranial measurements. The set consisted of five rules including seven cranial measurements. Its accuracy was even better than the classification rates achieved by the logistic regression models. Concerning the second dataset of nonstandard measurements, the best accuracy (88.3 %) was obtained by using classification models learnt by two algorithms – JRIP with a dataset preprocessed by the BestFirst selection algorithm and Ridor with preprocessing by the GeneticSearch selection algorithm. Our experiments show that for the two datasets mentioned above the rule-based models contain smaller sets of rules with shorter lists of measurements and achieve better classification accuracy results in comparison with decision tree-based models.

A DENSE APPROACH FOR COMPUTATION OF FACIAL SOFT TISSUE THICKNESS DATA

D. Toneva, **S. Nikolova**, S. Harizanov, D. Zlatareva, V. Hadjidekov

Objective: The present study aims to propose a dense approach for computation of facial soft tissue thickness (FSTT) data. For this purpose, three-dimensional surface models of the skull and skin were generated from computed tomography (CT) data and all possible skull-to-face distances were calculated for each skull-skin pair.

Material and methods: The CT images were obtained using a Toshiba Aquilion64 CT system. Based on the scan data for each individual, surface models of the skull and skin were created in InVesalius. The produced models represented orientable irregular dense triangulated meshes with properly oriented outward-pointing normals. The model postprocessing was performed in MeshLab and as a result only the face region from the models was kept. The skull-to-face distances were computed in CloudCompare using the M3C2 plugin.

Results: The M3C2 plugin provides measurements perpendicular to the skull surface along the direction of the outward-pointing normal vectors of the triangulated mesh. The measurements originate only from the front skull surface since the distance calculations were restricted to the positive half-space relatively to the normal. The number of calculated distances amounts to over 70,000 per skull-skin pair.

Conclusion: The M3C2 plugin enables computation and visualization of dense data of FSTTs.

Keywords: facial soft tissue thicknesses; CloudCompare; M3C2 plugin; surface models; CT; facial approximation

MACHINE LEARNING APPROACHES FOR SEX ESTIMATION USING CRANIAL MEASUREMENTS

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The aim of the present study is to apply support vector machines (SVM) and artificial neural network (ANN) as sex classifiers and to generate useful classification models for sex estimation based on cranial measurements. Besides, the performance of the generated sub-symbolic machine learning models is compared with models developed through logistic regression (LR). The study was carried out on computed tomography images of 393 Bulgarian adults (169 males and 224 females). The three-dimensional coordinates of 47 landmarks were acquired and used for calculation of the cranial measurements. A total of 64 measurements (linear distances, angles, triangle areas and heights) and 22 indices were calculated. Two datasets were assembled including the linear measurements only and all measurements and index, respectively. An additional third dataset comprising all possible interlandmark distances between the landmarks was constructed. Two machine learning algorithms—SVM and ANN and a traditional statistical analysis LR—were applied to generate models for sex estimation. In addition, two advanced attribute selection techniques (Weka BestFirst and Weka GeneticSearch) were used. The classification accuracy of the models was evaluated by means of 10×10-fold cross-validation procedure. All three methods achieved accuracy results higher than 95%. The best accuracy ($96.1 \pm 0.5\%$) was obtained by SVM and it was statistically significantly higher than the best results achieved by ANN and LR. SVM and ANN reached higher accuracy by training on the full datasets than the selection datasets, except for the sample described by the interlandmark distances, where the reduction of attributes by the GeneticSearch algorithm improved the accuracy.

Keywords: Machine learning . Artificial neural network . Support vector machine . Sex estimation . Cranial measurements . Computed tomography