UNESP - Universidade Estadual Paulista
“Júlio de Mesquita Filho”
Faculdade de Odontologia de Araraquara

Franciéllen de Barros

Análise de medidas lineares e volumétricas de seios paranasais de indivíduos brasileiros com vistas à identificação humana

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Tese apresentada à Universidade Estadual Paulista (Unesp), Faculdade de Odontologia, Araraquara para obtenção do título de Doutora em Ciências, na Área de Ciências Forenses.

Orientadora: Profª Drª Mônica da Costa Serra
Coorientador: Prof. Dr. Clemente Maia da Silva Fernandes

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Franciéllen de Barros

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Tese para obtenção do grau de Doutor em Ciências Forenses

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DADOS CURRICULARES

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Barros F. Análise de medidas lineares e volumétricas de seios paranasais de indivíduos brasileiros com vistas à identificação humana [tese de doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2022.

RESUMO

Foram avaliadas as possibilidades de identificação humana por meio da análise dos seios paranasais, e na estimativa do sexo, idade e ancestralidade (Publicação 1), de imagens 2D e 3D dos seios frontais e o papel do ortodontista nesse contexto (Publicação 2). Através do software DDS-Pro®, foram realizadas mensurações volumétricas dos seios maxilar (Publicação 3) e esfenoidal (Publicação 5), e mensurações lineares dos seios maxilar (Publicação 4), esfenoidal (Publicação 6) e frontal (Publicação 7), utilizando imagens de tomografia computadorizada de feixe cônico de indivíduos brasileiros, verificando a existência de diferenças entre os lados, e a correlação das medidas com sexo, idade, cor da pele e estado nutricional. A análise dos seios é uma ferramenta útil para a identificação e estimativa de sexo, idade e ancestralidade (1). A análise 2D e 3D dos seios frontais são de grande valia para a identificação (2). Não houve diferenças entre os lados, os sexos e o IMC, mas houve diferenças entre as idades e na cor de pele (3). Houve diferenças entre os lados, os sexos, as idades, todavia não houve diferenças entre a cor de pele e o IMC (4). Não houve diferenças entre os lados, os sexos e a cor de pele, mas houve diferenças entre as idades e IMC (5). Não houve diferença entre os lados, a cor de pele e o IMC, entretanto houve diferenças entre os sexos, as idades (6). Houve diferenças entre os lados, os sexos, as idades, contudo não houve diferenças entre cor de pele e IMC (7).

Palavras-chave: Ciências Forenses. Odontologia Legal. Seios paranasais. Tomografia Computadorizada de Feixe Cônico. Radiologia.

Barros F. Analysis of linear and volumetric measurements of paranasal sinuses of Brazilian individuals with a view to human identification [tese de doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2022.

ABSTRACT

The possibilities of human identification were evaluated by analyzing paranasal sinuses and estimating sex, age, and ancestry (Publication 1-P1) of 2D and 3D images of frontal sinuses. It also investigated the role of orthodontists in this context (Publication 2-P2). Volumetric measurements of maxillary (Publication 3-P3) and sphenoid (Publication 5-P5) sinuses and linear measurements of maxillary (Publication 4-P4), sphenoid (Publication 6-P6), and frontal (Publication 7-P7) sinuses were performed with the DDS-Pro™ software, using CBCT images of Brazilian individuals. The study verified potential differences between the sides and a correlation of measurements to sex, age, skin color, and nutritional status. It was found that: P1- Sinus analyses can be used for identification and sex, age, and ancestry estimations. P2- The 2D and 3D analyses of frontal sinuses are valuable for identification, and orthodontists must be aware of this possibility. P3- There were no differences for the sides, sexes, and BMI, but there were differences for ages and skin color. P4- There were differences for the sides, sexes, and ages, but there were no differences between skin color and BMI. P5- There were no differences for the sides, sexes, and skin color, but there were differences between age and BMI. P6- There were no differences for the sides, skin color, and BMI, but there were differences between the sexes and ages. P7- There were differences for the sides, sexes, and ages, but there were no differences between skin color and BMI.

Keywords: Forensic Sciences. Forensic Dentistry. Paranasal Sinuses. Cone-Beam Computed Tomography. Radiology.

SUMÁRIO

1 INTRODUÇÃO

No contexto pericial, o conjunto de caracteres físicos, psíquicos, funcionais e civis, normais ou patológicas, que individualizam uma pessoa, tornando-a única, diferente de todas as demais, qualificando-a como idêntica somente a ela mesma, é conceituado como identidade[1-3].

Por outro lado, as técnicas ou métodos por meio das quais a identidade de uma pessoa é estabelecida, permitindo distinguir uma da outra, são definidas como identificação[4,5].

Os métodos de identificação são objetivos, pois levam à identidade do indivíduo com base em dados científicos. A utilização dos métodos de identificação é necessária tanto em indivíduos vivos como em cadáveres, restos cadavéricos, ossada, e até mesmo em objetos, armas e vestes. Por serem comparativos, nos casos de óbitos, estabelecem um juízo de comparação entre dados anteriores à morte (dados *ante mortem*) com os dados posteriores (dados *post mortem*) à morte do indivíduo. Sendo assim, havendo a suspeita de que o corpo encontrado seja de um determinado indivíduo, os dados *ante* e *post mortem* devem ser comparados, para que seja estabelecida sua identidade[6,7].

A identificação *post mortem* possui o objetivo de estabelecer a identidade humana, sendo fundamental nas providências legais referentes ao óbito[8]. A identificação dos cadáveres, independente das circunstâncias que estes corpos foram descobertos (carbonizados, esqueletizados ou putrefeitos), é de grande importância, tanto por razões legais e jurídicas como humanitárias, para que providências concernentes ao óbito sejam tomadas, além de acalentar o emocional de parentes e amigos que possuem um ente querido falecido[8]. Para isto, a utilização de métodos de identificação necessários para se chegar à identidade do indivíduo, torna-se extremamente importante[9].

O processo de identificação apresenta-se de forma complexa, sistemática e organizada. A identificação mostra-se uma tarefa desafiadora, com grande significância, pois além de tratar de questões humanitárias, têm implicações diretas no âmbito de procedimentos civis e criminais[10].

No campo forense existem diferentes opções de métodos usuais de identificação imediata do indivíduo e, segundo a Interpol[11], os métodos considerados primários são a datiloscopia, a Odontologia Legal e a análise do perfil de DNA.

A análise das impressões digitais corresponde ao método mais utilizado, quando o tecido se encontra viável para manuseio. A análise de DNA, que traz como vantagem a alta precisão, em contrapartida é uma técnica com alto custo, que depende de muito tempo, laboratório apropriado e quando o material se encontra muito degradado o procedimento torna-se impraticável. A análise de dados odontológicos (Odontologia Legal) é prática, rápida e com baixo custo, costumando ser opção de escolha na impossibilidade de análise datiloscópica – claro, desde que haja dados de um primeiro registro disponíveis para comparação[2,11,12].

Os seios paranasais podem fornecer informações de grande valor para a identificação humana devido às particularidades dos seus contornos, permitindo uma análise meticulosa e explícita, amenizando os riscos de erros durante a investigação pelo perito[13]. Tais seios estão presentes em ambos os hemisférios da face, sendo constituídos por cavidades ósseas duplas, localizados lateralmente às fossas nasais e interligados por intermédio de canais e de orifícios ou óstios. São dois seios frontais, dois maxilares, dois esfenoidais e dois grupos de células etmoidais[14]. Segundo Sidhu et al.[15], desenvolvem-se como evaginações da mucosa nasal para o interior da porção óssea; durante o seguimento de remodelação óssea suas expansões ocorrem durante a reabsorção do osso pelos osteoclastos. Os seios maxilares formam-se a partir do quarto mês de vida embrionária por meio da absorção da porção central do osso maxilar, o que é diferente nos outros seios, que se desenvolvem mais tardiamente. Para o interior dos ossos adjacentes, aparecem como projeções das cavidades nasais e tornam-se cheias de ar[15].

Vários exames imagiológicos, como radiografias (Waters e panorâmica), ressonância magnética (RM), tomografia computadorizada (TC) e tomografia computadorizada de feixe cônico (TCFC), podem fornecer a visualização dos seios paranasais.

A radiografia é um método de identificação pessoal e é amplamente aceita para o desenvolvimento de uma técnica segura para análise de algumas estruturas anatômicas[16], pois fornece dados importantes ao processo de identificação.

Segundo Santoro et al.[17], a comparação radiográfica está entre os métodos utilizados para estabelecer a identidade dos indivíduos, e vem sendo utilizado há mais de 70 anos, fornecendo identificações cientificamente seguras. As radiografias odontológicas fornecem identificação por meio da análise do trabeculado ósseo, unidades dentárias, alvéolos, contornos de cavidades, seios faciais, entre outros[18].

Segundo Phothikhun et al.[19], a TCFC é aceita como um dos métodos pioneiros na avaliação e análise dos seios por cirurgiões-dentistas, radiologistas e otorrinolaringologistas. Além disso, pode fornecer informações para a identificação forense graças à individualidade dos contornos, devido às comparações entre os dados obtidos pelos métodos de imagem[20]. Desta forma, torna-se um método comparativo confiável de interesse forense para a identificação humana, entre os dados prévios com os que serão obtidos no momento presente da análise[21,22].

Diversos métodos de identificação são utilizados em Odontologia Legal, sendo o estudo dos seios paranasais de grande relevância[12]. Porém, estudos forenses utilizando tomografias computadorizadas ainda são poucos.

Não há na literatura dados de características métricas bi e tridimensionais de seios paranasais de indivíduos brasileiros, associando-as com sexo, idade, estado nutricional e cor da pele. Assim, estudos atuais, apresentando tais informações, desenvolvidos com amostra brasileira são necessários. Tais dados poderão contribuir, em casos periciais reais, para a identificação humana, auxiliando a Justiça e a sociedade.

2 PROPOSIÇÃO

Os objetivos do presente estudo foram:

2.1 Proposição Geral

Verificar se há diferenças entre os lados esquerdo e direito dos seios paranasais (seio frontal, seio maxilar e seio esfenoidal), e se há correlação das medidas lineares e volumétricas com sexo, idade, cor da pele e estado nutricional.

2.2 Proposições Específicas

Publicação 1: Avaliar as possibilidades de identificação humana através da análise dos seios paranasais, bem como na estimativa de sexo, idade e ancestralidade.

Publicação 2: Avaliar as possibilidades de identificação humana usando imagens 2D e 3D dos seios frontais e o papel de ortodontistas neste contexto.

Publicação 3: Realizar mensurações tridimensionais (volume e área) do seio maxilar (SM), a partir de imagens de tomografia computadorizada de feixe cônico (TCFC), e avaliar se há diferenças entre os lados esquerdo e direito, e se há correlação das medidas com sexo, idade, cor da pele e estado nutricional.

Publicação 4: Realizar mensurações lineares (bidimensionais) do seio maxilar (SM), com o emprego de imagens de tomografia computadorizada de feixe cônico (TCFC); analisar a influência do sexo, idade, cor da pele e estado nutricional (índice de massa corporal - IMC); verificar se há diferenças entre os lados direito e esquerdo.

Publicação 5: Realizar uma análise tridimensional (volume e área), a partir de tomografias computadorizadas de feixe cônico (TCFC) de população brasileira, do seio esfenoidal (SE), utilizando o software DDS-Pro® 2.14.2_2022 versão beta (DPP Systems, Czestochowa, Polônia) e avaliar se há correlação com sexo, idade, cor da pele e estado nutricional.

Publicação 6: Realizar mensurações lineares do seio esfenoidal (SE), a partir de imagens de tomografia computadorizada de feixe cônico (TCFC), analisando a influência do sexo, idade, cor da pele e estado nutricional (índice de massa corporal - IMC), além de verificar se há diferenças entre os lados direito e esquerdo.

Publicação 7: Realizar mensurações lineares de altura, largura e profundidade do seio frontal (SF) de uma amostra brasileira, a partir de imagens de Tomografia Computadorizada de Feixe Cônico (TCFC), analisando a influência do sexo, idade, cor da pele e estado nutricional (índice de massa corporal - IMC), além de verificar se há diferenças entre os lados direito e esquerdo.

3 PUBLICAÇÕES

Durante todo o meu doutorado foram realizados estudos métricos 2D e 3D com seios paranasais (seio frontal, seio maxilar e seio esfenoidal), verificando se há diferenças entre os lados esquerdo e direito, e se há correlação das medidas lineares e volumétricas com sexo, idade, cor da pele e estado nutricional. Antes de iniciar o trabalho experimental, foi realizada uma ampla revisão da literatura para obtenção de informações referentes à base teórica, aplicada na abordagem do tema e na questão do estudo. Sendo assim, a partir da criteriosa análise da literatura científica publicada sobre o mote, foi obtido o embasamento teórico e definida a metodologia para o desenvolvimento da parte experimental da pesquisa.

3.1 Publicação 1[1*]

Paranasal sinuses and human identification

Abstract

The characteristics of the paranasal sinuses (maxillary, frontal, sphenoid and ethmoid sinuses) are information of great relevance to Forensic Sciences, as their images can be used for human identification purposes. Due to their particularities, the paranasal sinuses provide valuable information for human identification, reducing the risk of errors during investigation by experts. Such structures are visualized from several imaging exams. This study evaluates the possibilities of human identification through the analysis of the paranasal sinuses, as well as the effectiveness of their analysis in estimating sex, age and ancestry. A comprehensive search was performed in the PubMed, SciELO, LILACS, and Web of Science databases. As inclusion criteria, texts that addressed the subject were selected. Imaging analysis of the frontal, maxillary and sphenoid sinuses is a useful tool for human identification, as well as for estimating sex, age and ancestry; usually provides a high level of accuracy. Regarding the ethmoid sinus, research is indicated to verify its use in human identification, as no publications on this specific subject were found. Additional research must be carried out (especially three-dimensional analysis of the paranasal

[1*]Artigo publicado e descrito segundo as normas do periódico *Research, Society and Development* (Confira a autorização da editora para publicação no Anexo A).

sinuses), to develop standardized protocols, improving the work of experts, helping justice and society.
Keywords: Forensic sciences; Human identification; Forensic anthropology; Forensic dentistry; Forensic imaging and radiology; Paranasal sinuses; Frontal sinus; Maxillary sinus; Sphenoid sinus; Ethmoid sinus.

Resumo

As características dos seios paranasais (seios maxilares, frontais, esfenoidais e etmoidais) são informações de grande relevância para as Ciências Forenses, pois as suas imagens podem ser utilizadas para fins de identificação humana. Devido às suas particularidades, os seios paranasais fornecem informações valiosas para a identificação humana, diminuindo os riscos de erros durante a investigação pelos peritos. Tais estruturas são visualizadas a partir de vários exames imaginológicos. Este estudo avalia as possibilidades de identificação humana por meio da análise dos seios paranasais, bem como a efetividade da análise dos mesmos na estimativa do sexo, idade e ancestralidade. Uma busca abrangente foi realizada nas bases de dados PubMed, SciELO, LILACS e Web of Science. Como critérios de inclusão foram selecionados textos que abordavam a temática. A análise imaginológica dos seios frontal, maxilar e esfenoidal é uma ferramenta útil para a identificação humana, bem como para estimativa de sexo, idade e ancestralidade; geralmente fornece um alto nível de precisão. Em relação ao seio etmoidal, são indicadas pesquisas para verificar seu uso na identificação humana, pois não foram encontradas publicações sobre este mote específico. Pesquisas adicionais devem ser realizadas (especialmente análises tridimensionais dos seios paranasais), para desenvolver protocolos padronizados, melhorando o trabalho dos peritos, auxiliando a Justiça e a sociedade.
Palavras-chave: Ciências forenses; Identificação humana; Antropologia forense; Odontologia legal; Imaginologia e radiologia forense; Seios paranasais; Seio frontal; Seio maxilar; Seio esfenoidal; Seio etmoidal.

Resumen

Las características de los senos paranasales (maxilar, frontal, esfenoides y etmoides) son información de gran relevancia para las Ciencias Forenses, ya que sus imágenes pueden ser utilizadas con fines de identificación humana. Por sus particularidades, los senos paranasales proporcionan información valiosa para la identificación humana, reduciendo el riesgo de errores durante la investigación por parte de expertos. Estas estructuras se visualizan a partir de varios exámenes por imágenes. Este estudio evalua las posibilidades de identificación humana a través del análisis de los senos paranasales, así como la efectividad de su análisis en la estimación de sexo, edad y ancestralidad. Se realizó una búsqueda exhaustiva en las bases de datos de PubMed, SciELO, LILACS y Web of Science.Como criterio de inclusión se seleccionaron textos que abordaban el tema. El análisis imaginológico de los senos frontal, maxilar y esfenoidal es una herramienta útil para la identificación humana, así como para estimar el sexo, la edad y la ancestralidad; generalmente proporciona un alto nivel de precisión. En cuanto al seno etmoidal, está indicada la investigación para verificar su uso en la identificación humana, ya que no se encontraron publicaciones sobre este tema específico. Se deben realizar investigaciones adicionales (especialmente análisis tridimensional de los senos paranasales), para desarrollar protocolos estandarizados, mejorando el trabajo de los expertos, ayudando a la justicia y la sociedad.

Palabras clave: Ciencias forenses; Identificación humana; Antropología forense; Odontología forense; Radiología e imagenología forense; Senos paranasales; Seno frontal; Seno maxilar; Seno esfenoidal; Senos etmoidales.

1. Introduction

The identity of a person corresponds to a set of physical, functional or psychological, and normal or pathological characteristics, making the individual identical only to himself. The identification process is complex, systematic, and organized, and the main objective is to determine the identity of the individual in evidence. It is a comparative process, meaning it necessarily needs to compare data knowingly from an individual with the corresponding data from the subject to be identified (Neves et al., 2021; Andrade et al., 2021; Barros et al., 2021a; Gioster-Ramos et al., 2021; Kuhnen et al., 2021; Barros et al., 2021b; France, 2017; Xavier et al., 2015; Nikam et al., 2015). However, this is a challenging task for mankind although of great importance, because besides dealing with humanitarian issues, it also directly impacts civil and criminal proceedings (Dostalova et al., 2012).

Decomposing, skeletonized, or charred corpses, especially in large-scale accidents, usually need to be identified, requiring the use of anthropological methods (Singh et al., 2013). This occurs particularly when there is no suspicion about the identity of the deceased, which often requires assessing the biological profile of the subject.

In the absence of ante-mortem data leading to personal identities, the biological profile helps to reduce the number of suspects investigated using identification methods (Passalacqua, 2009; Klales, Kenyhercz, 2015).

Identification methods have a comparative characteristic between ante-mortem and post-mortem data. According to Interpol (2018), the primary methods are fingerprint analysis, DNA verification, and Forensic Dentistry (Fernandes, 2010). However, for these methods to be valid they must fulfill some requirements such as immutability, uniqueness, practicability, permanence, and classifiability (França, 2017).

The use of anthropological methods is necessary when bodies that require identification are found (Singh et al., 2013) but there is no suspicion about the identity of the subjects. To determine individual characteristics, aiding the identification process, it is timely to analyze the bones of the skull, pelvis, and femur, as well as the sella turcica, mastoid cells, and paranasal sinuses (Cox et al. 2009).

Due to the particularity of their contours, paranasal sinuses provide valuable information for human identification, reducing the risk of errors by forensic professionals during the investigation (Barros et al., 2021b; Gioster-Ramos et al., 2021; Musse, 2009). Paranasal sinuses are arranged in the two facial hemispheres and classified, according to their anatomical relationships, into maxillary sinus (MS), ethmoid sinus (ES), frontal sinus (FS), and sphenoid sinus (SS) (Keir, 2009; Gallup, Hack, 2011; Ebrahimnejad et al., 2016).

Several imaging tests such as Waters and panoramic radiographs, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Cone-Beam Computed Tomography (CBCT) can provide the visualization of paranasal sinuses, but recently CBCT has become an adequate imaging method for analyzing sinuses due to its higher resolution, lower radiation, and lower cost than traditional CT (Scarfe et al., 2006). Furthermore, due to the characteristics of their contours and the comparison between the data obtained by imaging methods, paranasal sinuses can provide information for forensic identification (Lee et al., 2004).

This study evaluates the possibilities of human identification through the analysis of paranasal sinuses, as well as the effectiveness of their analysis in estimating sex, age, and ancestry.

2. Methodology

This study was based on a descriptive literature review with a qualitative approach (Pereira et al., 2018), constituting an extensive study and allowing the inclusion of experimental and non-experimental research and theoretical and empirical literature to deepen the knowledge on the subject studied. A comprehensive search was performed in the PubMed, SciELO, LILACS, and Web of Science primary databases. The descriptors used were "paranasal sinus", "frontal sinus", "maxillary sinus", "ethmoid sinus", "sphenoid sinus", "human identification", "radiographic images", "cone-beam computed tomography", "threedimensional images ", "sex", "age", and "ancestry". Initially, the descriptors were searched individually, and then crossings were made between them. The sample was selected by including articles, dissertations, and theses that were available in full, published in Portuguese or English, at any period, and referred to the topic studied. Exclusion criteria were texts published in languages other than English and Portuguese and not related to the topic studied. The research was classified and evaluated, ending with the interpretation of results and synthesis of knowledge. This article also has a theoretical and reflective approach on the biological profile characteristics that contribute as an auxiliary forensic method of human identification through the analysis of paranasal sinuses.

3. Results and Discussion

3.1 Anatomy and embryology of paranasal sinuses

Positioned in the bones that comprise the nasal cavity, paranasal sinuses are named according to anatomical relationships as maxillary sinus, ethmoid sinus, frontal sinus, and sphenoid sinus (Keir, 2009; Gallup, Hack, 2011; Ebrahimnejad et al., 2016). As they are composed of air, they are classified as pneumatic cavities and lined by the mucoperiosteal membrane covered by the ciliated cylindrical pseudostratified epithelium, determining a direct or indirect communication with the respiratory system. They can ensure the harmony of facial growth and lighten the skull, protecting infraorbital and intracranial structures, protecting against injuries, and partially neutralizing impacts (Batista et al., 2011).

For Orhan et al. (2017), due to their location, the sinuses cooperate to the development of facial structures, jaws, and upper airways; humidification and heat of inspired air; thermal insulation; increased voice resonance; cranial structure weight; and expansion of olfactory surfaces. Additionally, sensitive structures are insulated from the rapid fluctuations of temperature in the nose. Paranasal sinuses also help to improve nasal function and nitric oxide production, which contribute to nasal immune defense (Keir, 2009).

The nasal cavity is a roughly cylindrical midline airway that extends forward from the wing of the nose to the posterior nostril. On each side, it is surrounded by the maxillary sinus and covered by the frontal, ethmoid, and sphenoid sinuses, front to back. Although it seems simple, the nasal anatomy is composed of complex and subdivided airways connecting to the sinuses. The four paranasal sinuses paired and aligned with the pseudostratified columnar epithelium are 1. maxillary sinus: the largest sinus, located in the maxilla; 2. frontal sinus: located above the eyes, inside the frontal bone; 3. ethmoid sinus: several discrete air cells in the ethmoid bone between the nose and eyes; 4. sphenoid sinus: located within the sphenoid bone (Cappello et al., 2020).

3.1.1 Maxillary sinus

In the embryonic period, the alveolar processes are close to the orbital edge, which contains tooth germs. The lateral wall of the nasal cavity is membranous, starting an invagination in the middle meatus region, forming a sinus sac toward this maxillary region and located medially to it. At birth, the maxillary sinus (MS) is small and located medially to the orbit. When children are born, they have a rudimentary slit-shaped ethmoidal labyrinth and maxillary sinus. The MS develops up to fifteen years of age. In the first year of life, the maxillary sinus descends from the orbit without reaching the infraorbital nerve canal. After sinus pneumatization, in the second year, it reaches the canal and surpasses it in the following two years. The entire development of the maxillary sinus depends on teeth eruption and ends when the permanent dentition descends, including the third molar. It is worth noting that the floor of the maxillary sinus of children is higher than the floor of the nasal cavity and as high as the middle meatus. Only at nine years old the floors of the maxillary sinus and the nasal cavity are aligned (Physiology and Endoscopic Nasosinusal Anatomy, 2011).

The dimensions of the MS vary individually, but on average, the base in an adult is 35 mm and the height is 25 mm (Raja, 2009). These measures vary according to age, ancestry, sex, and personal conditions. Maxillary sinuses are presented in pairs, located in the body of the jaws, and on both sides. They have a square pyramid shape with the bottom facing the lateral wall of the nasal cavity. The apex corresponds to the junction of the maxillary zygomatic process with the zygomatic bone and, in some cases, extending internally. The apex is usually located 25 mm from the base. The sides of this pyramid refer to the following maxillary surfaces: the upper wall or the top of the maxillary sinus corresponds to the orbital aspect of the maxilla, on the floor of the orbit; the front wall corresponds to the anterior surface of the maxilla; the posterior wall corresponds to the infratemporal aspect of the maxilla and separates the sinus from the infratemporal fossa; and the inferior wall or inferior part of the maxillary sinus corresponds to the alveolar process of the maxilla (Batista et al., 2011).

According to Pfaeffli et al. (2007), the MS radiography used to recognize individuals can be considered a complementary examination, providing relevant data to professional knowledge with standardized methods. For identification, the morphometric measurements of the maxillary sinus are compared with the shape, size, and contour of the images available.

The morphology and metrics of maxillary sinuses can be used to estimate sex and for human identification (Musse et al., 2009) (Musse et al., 2011). The literature reports cases of identification performed by comparing the ante-mortem and postmortem characteristics of the morphology of maxillary sinuses (Musse et al., 2011).

3.1.2 Frontal sinus

The frontal sinus (FS) starts to develop in the fourth or fifth week of pregnancy, continuing through adolescence or early adulthood. The FS begins as an insignificant pneumatization of the newborn and is radiologically visible around four years of age. Craniofacial growth is synchronized with the frontal sinus. (Duke, Cassiano, 2005).

Frontal sinuses are bilaterally divided by the main septum and there may be additional septa with varying sizes. They originate in the anterior part of the middle meatus (frontal recess) but they can also originate from an anterior ethmoidal cell that invades the frontal bone (Mafee, 1991; Babbel, 1991; Harnsberger et al., 1991; Laine, 1992; Scuderi et al., 1993; Nasosinusal Physiology and Endoscopic Anatomy, 2011). The FS drains through the frontal nasal canal to the frontal recess, the stenosis between the frontal sinus and the anterior middle meatus usually located in the anterosuperior portion of the infundibulum, and through the semilunar hiatus to the anterior part of the middle meatus, where they converge from the flow of the ipsilateral maxillary sinus. It can also drain directly into the middle meatus, above the infundibulum (Mafee, 1991; Babbel, 1991; Harnsberger et al., 1991; Laine, 1992; Scuderi et al., 1993).

The frontal sinus is undeveloped in 4% of people and its full development occurs between the ages of 10 and 12 (Hungary, 2000). The growth of the skull base and its anterior and middle fossae is centered in the sphenoid and ethmoid bones, and all neural and visceral bone architecture relates to it in anatomy and function. The interrelationships between these elements have been the basis for determining the constitutional type since childhood, and changes in this process can lead to craniofacial dysmorphisms (Mafee, 1991; Babbel, 1991; Harnsberger et al., 1991; Laine, 1992; Scuderi et al., 1993).

According to Nikam et al. (2015), both the height and the maximum width of the frontal sinus are unique characteristics of each individual. Silva et al. (2019) reported that the morphological information of frontal sinuses converges between antemortem and post-mortem radiographs for both metric and non-metric evidence, allowing to identify subjects.

Several studies have analyzed frontal sinus images for human identification, such as Silva et al. (2008), Falguera et al. (2008), Silva et al. (2009), Besana et al. (2010), David and Saxena (2010), Patil et al. (2012), Kim et al. (2013), Beaini et al. (2015), among others. Using CBCT as an imaging method, Marques et al. (2014), Cossellu et al. (2015), and Soares et al. (2016) described the use of the frontal sinus for human identification in forensic investigations.

Therefore, Zhao et al. (2021) developed standardized techniques to classify the frontal sinus according to its 3D morphological measurements and found the usefulness of the 3D model in identifying the Han Chinese population. Pereira et al. (2021) performed a systematic literature review to verify the existing methodological techniques, showing the advantages and limitations of the frontal sinus morphological assessment for human identification through two-dimensional or three-dimensional images of the maxillofacial region. According to the research, most studies showed a low risk of bias. Li et al. (2021) explored an innovative procedure for assessing the individuality of the frontal sinus based on a 3D-3D overlay procedure for comparative forensic identification.

3.1.3 Sphenoid sinus

The sphenoid sinus (SS) develops from the third month of pregnancy. During this period, the nasal mucosa invades the posterior part of the cartilaginous nasal capsule, forming a pouch-like cavity. In the last few months of fetal development, the wall around the cartilage ossifies. In the second and third years of life, the cartilage is reabsorbed and the cavity is fixed to the sphenoid body. At around six or seven years of age, the vaporization of the sphenoid sinus progresses and, by the age of 12, its pneumatization is completed, with pneumatization of anterior clinoids and the pterygoid process (Cappello et al. 2020).

In the first years after birth, the SS originates from the invagination of the mucosa to the sphenoethmoidal recess, continuing its pneumatization process by invading the sphenoid bone until puberty (Endoscopic Nasosinusal Anatomy and Physiology, 2011).

Sphenoid sinuses are the most posterior of the paranasal sinuses. They are usually "immersed" in the cleft and are limited in the upper back by the sella turcica. Their ostia are positioned medially in the anterosuperior portion of the anterior wall of each sinus, communicating with the sphenoethmoidal recess in the posterior part of the superior meatus. The sphenoethmoidal recess appears lateral to the nasal septum and can sometimes be seen on CT images in coronal slices, but is best seen in sagittal or axial slices (Babbel, Harnsberger, 1991; Harnsberger et al., 1991; Scuderi et al., 1993; Zinreich, 1998).

Auffret et al. (2016) evaluated the validity of the anatomical visual comparison of the CT of sphenoid sinuses in forensic identification. According to the authors, this sinus is useful because identification accuracy was 100%.

Thus, the anatomical individuality of this sinus can be validly applied in forensic contexts for human identification (Capella et al., 2019).

3.1.4 Ethmoid sinus

The ethmoid sinus (ES) originates from the invagination of the mucosa of the middle and superior meatus and is located between the maxillary sinus, the eyeball, and the brain. Its growth is allowed by the fovea ethmoidalis and, depending on the development of the cribriform plate and the roof of the ethmoidal bone at birth, the volume of all its cells is similar to that of the maxillary sinus. Anterior ethmoid cells reach the same height as the superior orbital ridges at five years of age (Endoscopic Nasosinusal Physiology and Anatomy, 2011).

There are three to four cells at birth and 10 to 15 cells in adulthood, with a total volume of 2 to 3 ml, which are located between the eyes. The anterior ethmoids drain into the ethmoid infundibulum, in the middle meatus. The posterior ethmoid sinus drains into the sphenoethmoidal recess in the upper nasal passage. The ES is supplied by the anterior and posterior ethmoid sinus arteries, which are branches of the ophthalmic artery. The ophthalmic artery is a branch of the internal carotid artery (Cappello et al. 2020).

The ethmoid sinus is usually the most complex of the paranasal sinuses, with a highly variable anatomical structure and a close relationship with the orbit and the base of the skull. The first ES cell found is the ethmoidal bulla, which is located behind the semilunar hiatus and in front of the basal lamella. It is a circular structure with the side attached to the papyraceous lamina (Kuan, Palmer, 2021). The ethmoid sinus is composed of many thin-walled air cells, some of which may extend forward between the lacrimal sac and the nasal mucosa (Nerad, 2021).

3.2 Paranasal sinuses and human identification

Due to their characteristics and contours, paranasal sinuses can provide valuable information for human identification through detailed and clear analyses, reducing the risk of errors by the expert in the investigation process.

The radiological assessment of paranasal sinuses and related structures is designed to accurately describe the anatomical area and confirm any skeletal changes or changes in the sinus mucosa and fluid level, and determine the existence and extent of pathologies (Fatterpekar et al. 2008; Ritter et al., 2011).

Several authors have evaluated the maxillary, frontal, and sphenoid sinuses, relating them to possibilities of human identification with extraoral radiographs (Riepert et al., 2001; Pfaeffli et al., 2007; Silva et al., 2009) and CT scans (Perella et al., 2003; Pfaeffli et al., 2007; Tatlisumak et al., 2008; Uthman et al., 2010). Gioster-Ramos et al. (2021) point out that the uniqueness of their structures individualizes people, thus paranasal sinuses can be used for human identification. Currently, the use of CT allows three-dimensional analyses, which greatly enriches and increases the resources available from Forensic Sciences and helps justice and society to establish the human identity.

Ruder et al. (2012) assessed the reliability of radiological identification through the visual comparison of CT of paranasal sinuses before and after death and confirmed that the visual comparison of CT of the skull is a robust and reliable method to identify unknown cadavers.

For many years, traditional radiographs were used to study sinuses (Cagici et al., 2005). However, due to overlapping, two-dimensional radiographic images are difficult to interpret (Liang et al., 2010). Conversely, with technological advances, CBCT has become a valuable method for evaluating sinuses because interactive and three-dimensional images have a great impact on head images, improving the ability of professionals to accurately describe the condition and location of sinuses (Cakli et al., 2012; Poorey, Gupta, 2014).

3.3 Paranasal sinuses for estimating the biological profile: sex, age, and ancestry

The study of anthropometry is essential to clarify issues related to human identification for being highly important for linear and angular measures and measuring the area and volume of different parts of the body (Garcia, 2014). The anthropometric analysis of bones provides basic characteristics of the individual, such as sex, age at death, ancestry, and height (Fernandes, 2010).

In the forensic context, the construction of the biological profile with individual characteristics is important. When unknown bodies are found and taken to the Forensic Medical Institute, forensic anthropologists initially estimate sex and age at death (Kim et al., 2006). Ancestry and stature are variables that, along with the previous two, constitute the so-called biological profile of an individual.

Some authors developed studies with paranasal sinuses to estimate sex, age, and ancestry (Camargo, 2000; Garcia, 2014; Sidhu et al., 2014; Saccucci et al., 2015; Araújo et al., 2015; Moore. Ross, 2017; Rani et al., 2017; Özer et al., 2018; Demiralp et al., 2019; Najem et al., 2020; Robles et al., 2020).

A comprehensive description of sex based on skeletal characteristics is a basic step in forensic investigations (Franklin et al., 2006; Franklin et al., 2008). For Carvalho (2012), estimating the sex of an individual is one of the most important analyses in human identification processes. To determine sexual dimorphism across the skull structure, a visual comparison of bones or measurement of cranial components can be performed.

Age estimation in forensic clarification is important, as it helps to identify corpses and classify individuals into capable and absolutely and relatively incapable, which information has an important forensic function (Schmidt, 2004).

Ancestry estimation is performed through morphological characteristics and bone measurements, which facilitates compatibility with established ancestral groups (Ousley et al., 2009). However, the presence and maintenance of bone elements are required for morphological or metric analyses, as well as for assessing the age and sex of individuals (Batista, Santos, 2018).

Brazil has a mixed population, which makes it difficult to determine the biological characteristics (biological profile) of the ancestral pattern when comparing foreign populations with their anthropometric characteristics and differences. Therefore, to obtain reliable information, forensic anthropologists must prudently use protocols and methods (Almeida Júnior et al., 2010), especially those developed with parameters obtained from studies with other populations.

Among the parameters for estimating biological characteristics, ancestry is the most difficult, researched, and controversial (Vanrell, 2019). Due to the scarcity of research in this area, especially in highly mixed populations such as Brazil, its estimation is a challenge (Batista, Santos, 2018).

The CT is described as one of the potential imaging methods that can help forensic professionals to identify the human body, especially CBCT (Phothikhun et al., 2012; Hishmat et al., 2014; Silveira, 2015). Regarding paranasal sinuses, these methods allow accurate assessments and analyses (Pfaeffli et al., 2007; Tucunduva, Freitas, 2008). There are several studies in the literature that used radiographic images to verify whether the frontal, maxillary, and sphenoid sinuses provide support for recognition in estimating sexual dimorphism, age, and ancestry. As for the ethmoid sinus, no data were found relating it to these variables.

However, Robles et al. (2020) performed a study to propose a new method to determine biological characteristics with the three-dimensional (3D) reconstruction of paranasal sinuses to estimate age, sex, and ancestry. The findings of this study provide insights into the potential of using paranasal sinuses as an attribute to distinguish individuals and identify unknown human remains in forensic investigations.

Thus, in 2017, Sherif et al. determined the accuracy of using paranasal sinuses measurements as a method of estimating sex with multi-detector computed tomography. According to the results, the maxillary sinus presents the highest precision in estimating sexual dimorphism, followed by the frontal sinus and sphenoid sinus, and concluding the effectiveness of its use for human identification.

Demiralp et al. (2019) analyzed CBCT images of a sample of ancient skulls to determine whether the dimensions and volume of paranasal sinuses could be useful to identify the estimate of sex and age. The results did not show statistically significant differences between measurements ($p < 0.05$) and the authors concluded that the measurements of volume and dimensions of the sinus from CBCT data can be a promising technique for determining sex and age.

Some studies, such as by Sidhu et al. (2014), Garcia (2014), Kanthem et al. (2015), Araújo et al. (2015), Tambawala et al. (2016), Prabhat et al. (2016), Bangi et al. (2017), Paknahad et al. (2017), Farias Gomes et al. (2019), Mohamed et al. (2020), Sathawane et al. (2020), and Soares et al. (2020) verified the accuracy and reliability of the maxillary sinus in sexual estimation and the results of all of them showed that this sinus can be used for such a purpose.

Likewise, Teixeira et al. (2020) evaluated, with CBCT, whether the maxillary sinus can be used to estimate sex and age. All measurements were greater in men and, regarding age, the youngest group had greater height measurements. According to the authors, the measurement of the maxillary sinus in CBCT images can be applied to sexual dimorphism in a complementary way, but for age estimation, the use of the maxillary sinus was less accurate.

The study by Araújo et al. (2015), using CBCT images, also had important implications for sex estimation, as it presented a statistically significant difference ($p=0.0005$) between the sexes, with a greater volume of MS observed in male individuals. However, regarding ancestry, it did not find a significant difference ($p=0.4535$) for brown and white individuals. Similarly, Soares et al. (2020) analyzed CBCT images and investigated sexual dimorphism in the Brazilian population, as well as the possibility of human identification through the maxillary sinus. The results show significant differences between the sexes. It was concluded that the evaluation of morphological and dimensional parameters of the MS are reproducible and thus considered valid for human identification.

In the same sense, Faria Gomes et al. (2019) developed and validated a formula to estimate sex with measurements of maxillary sinuses, using CBCT in a Brazilian population. The measurements of maxillary sinuses were significantly greater in men, with height being the most dimorphic measure and presenting an accuracy of 77.7% for sex estimation, which can be a complementary method for human identification in the Brazilian population. The data obtained in the study by

Uthman et al. (2011) also found a relationship between sex and measurements of the maxillary sinus. These authors analyzed reconstructed helical CT images and studied the accuracy and reliability of MS measurements for sex estimation, obtaining positive outcomes for the use of MS in the study of sexual dimorphism, with an overall accuracy of 71.6%.

The study by Najem et al. (2020) showed a divergent result. To estimate sex and age, these authors used CBCT images and performed linear measurements of the maxillary sinus. The results showed that the sample studied did not present statistically significant differences in the measurements, which could not be used to determine such parameters. The same occurred in the study by Etemadi et al. (2017). These authors evaluated the volume of the maxillary sinus with CBCT and analyzed its association with sex and some craniofacial indices. The average volume of the MS was higher in men. However, this parameter cannot be used for sex estimation because the area under the receiver operating curve (ROC) was 62.7%. The study by Gulec et al. (2020), performed with CBCT in a Turkish subpopulation, was also contradictory, as the authors did not find a relationship of MS volume with sex and age.

Using magnetic resonance imaging, Rani et al. (2017) estimated age and sex with the size and volume of the maxillary sinus. The results showed sexual dimorphism and a statistically significant difference. There were no statistically significant differences for the estimated age. Regarding the characteristics of the frontal sinus, Camargo (2000) concluded that the morphological analysis (area and perimeter) of this sinus can help to estimate sex. Likewise, Xavier et al. (2015) concluded that the FS is useful for human identification by conducting a literature review of 30 articles to assess the contribution of frontal and maxillary sinuses in Forensic Sciences to human identification and sex estimation. In 2017, Moore & Ross found that the frontal sinus is valid for estimating age and accurately predicting the age of subadults (Moore & Ross, 2017).

Scendoni et al. (2021) implemented a study on frontal sinuses, which involved the development of a personal code using the method presented by Cameriere et al. (2020), besides the variables considered by Yoshino et al. (1987) for the personal identification of Italians, Kosovars, and Turks to test the aforementioned approach and compare the results between the three different populations. According to the authors, this method is suitable for different groups of people. When comparing frontal sinus radiographs before and after death, the possibility of identifying a person increases significantly. The results show that the model is more discriminative in identifying individuals of different nationalities. Similarly, Abdalla (2021) measured the anteroposterior length, width, and height of the FS in different age groups of both sexes with axial, coronal, and sagittal tomography. The results showed statistical differences that can have considerable value in determining the sex, age, racial origin, and ethnic group for living or dead individuals.

As for the sphenoid sinus, according to Oliveira et al. (2009), it has great individual differences in area and volume, and it can be used to assess sexual dimorphism. The results of the study by Özer et al. (2018) showed that the SS can be used to estimate the sex and age of human remains, as well as determine age-related changes and population differences. Considering the Brazilian population and the sphenoid sinus to identify individuals, Ramos et al. (2021) performed linear and volumetric measurements of the SS with CBCT and concluded that these measurements are useful to characterize the sex of individuals. However, in the study by Oliveira et al. (2017), performed with helical CT, there were no significant correlations between age, sex, and sphenoid sinus volume.

4. Conclusion

The imaging analysis of frontal, maxillary, and sphenoid sinuses is a useful tool for human identification, as well as for estimating sex, age, and ancestry, as it commonly provides a high level of accuracy. Along with the two-dimensional analysis of sinuses, three-dimensional images are highly relevant for human identification. Although the three-dimensional analysis is still not routine, its use in Forensic Sciences is without a doubt an excellent means provided by new technologies.

Additional research must be carried out to create standardized protocols using new technologies, especially the 3D analysis of paranasal sinuses, to improve the work of forensic professionals, assisting justice and society. Regarding the ethmoid sinus, studies must be performed to verify its use for human identification, as there is no published data on the subject.

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3.2 Publicação 2[2*]

Orthodontic 2D and 3D frontal sinus imaging records: an important role in human identification

Abstract

Two-dimensional imaging records, as conventional radiographies, are part of the orthodontic clinic routine; frontal sinus images are often present in these exams. The characteristics of the frontal sinus are information of great relevance for the Forensic Sciences, as their images may be used for human identification purposes. With the advent of new threedimensional technologies and computerized image examinations such as Computed Tomography (CT), threedimensional analysis of the frontal sinuses has become possible. This article evaluates the possibilities of human identification using frontal sinuses 2D and 3D images and the role of orthodontists in this context. Pubmed, SciELO, LILACS and Web of Science were used as databases. As inclusion criteria, were selected texts concerning the studied issue. Although the analysis of frontal sinuses is traditionally carried out using two-dimensional images, there is a growing trend of studies employing CT scans. Cone-Beam Computed Tomography (CBCT) is an important diagnosis tool, more frequently used in orthodontics, which allows a three-dimensional approach and great precision in measurements. Together with two-dimensional analysis of frontal sinuses, 3D images are of great value for human identification. Although three-dimensional analysis is not yet a routine, its Forensic use is undoubtedly an excellent tool provided by new technologies. It is important that the orthodontist knows this possibility by properly keeping the patients' imaging exams.

Keywords: Forensic dentistry; Orthodontics; Three-dimensional imaging; Cone-beam computed tomography; Frontal sinus; Forensic sciences.

Resumo

Registros de imagens bidimensionais, como as radiografias convencionais, fazem parte da rotina da clínica ortodôntica; imagens do seio frontal estão frequentemente presentes nesses exames. As características do seio frontal são informações de grande relevância para as Ciências Forenses, pois suas imagens podem ser utilizadas para fins de identificação humana. Com o advento de novas tecnologias tridimensionais e exames de imagem computadorizados, como a tomografia computadorizada (TC), a análise tridimensional dos seios frontais tornou-se possível. Este artigo avalia as possibilidades de identificação humana por meio de imagens 2D e 3D dos seios frontais e o papel do ortodontista nesse contexto. Foram

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utilizadas como bases de dados: Pubmed, SciELO, LILACS e Web of Science. Como critérios de inclusão foram selecionados textos que retratassem a temática. Embora a análise dos seios frontais seja tradicionalmente realizada por meio de imagens bidimensionais, há uma tendência crescente de estudos com tomografia computadorizada. A Tomografia Computadorizada de Feixe Cônico (TCFC) é uma importante ferramenta diagnóstica, mais utilizada na Ortodontia, que permite abordagem tridimensional e grande precisão nas medidas. Juntamente com a análise bidimensional dos seios frontais, as imagens 3D são de grande valor para a identificação humana. Embora a análise tridimensional ainda não seja uma rotina, seu uso Forense é, sem dúvida, excelente ferramenta proporcionada pelas novas tecnologias. É importante que o ortodontista conheça essa possibilidade guardando de maneira adequada os exames de imagem dos pacientes.

Palavras-chave: Odontologia Legal; Ortodontia; Imagem Tridimensional; Tomografia computadorizada de feixe cônico; Seio frontal; Ciências forenses.

Resumen

Los registros de imágenes bidimensionales, como las radiografías convencionales, son parte de la rutina de la clínica de ortodoncia; las imágenes del seno frontal están presentes con frecuencia en estos exámenes. Las características del seno frontal son información de gran relevancia para las Ciencias Forenses, ya que sus imágenes pueden ser utilizadas con fines de identificación humana. Con el advenimiento de las nuevas tecnologías tridimensionales y los exámenes de imágenes computarizados, como la tomografía computarizada (TC), se ha hecho posible el análisis tridimensional de los senos frontales. Este artículo evalua las posibilidades de identificación humana a través de imágenes 2D y 3D de los senos frontales y el papel del ortodoncista en este contexto. Se utilizaron como bases de datos Pubmed, SciELO, LILACS y Web of Science. Como criterio de inclusión, se seleccionaron textos que retrataran el tema. Aunque el análisis de los senos frontales se ha realizado tradicionalmente mediante imágenes bidimensionales, existe una tendencia creciente en los estudios con tomografía computarizada. La tomografía computarizada de haz cónico (CBCT) es una importante herramienta de diagnóstico, más utilizada en ortodoncia, que permite un abordaje tridimensional y una gran precisión en las mediciones. Junto con el análisis bidimensional de los senos frontales, las imágenes en 3D son de gran valor para la identificación humana. Aunque el análisis tridimensional aún no es una rutina, su uso forense es sin duda una excelente herramienta proporcionada por las nuevas tecnologías. Es importante que el ortodoncista conozca esta posibilidad conservando adecuadamente los exámenes por imágenes del paciente.

Palabras clave: Odontología forense; Ortodoncia; Imagen tridimensional; Tomografía computarizada de haz cónico; Seno frontal; Ciencias forenses.

1. Introduction

Frontal sinuses are bilateral structures and, like fingerprints, they are unique in each individual. They are commonly observed in imaging exams asked by orthodontits, as radiographies and tomographies. So they are part of patients' dental records. And, as frontal sinuses present a different morphology for each person, they can be employed for human identification.

The identification process presents itself in a complex, systematic and organized way; its main objective is to verify the identity (a set of physical, functional or psychological, normal or pathological characteristics, which qualifies the individual as identical only to himself) of a person (Xavier et al., 2015; Nikam et al., 2015). Identification is a challenging task for humanity, although it presents great significance, because in addition to addressing humanitarian issues, it has direct implications in civil and criminal procedures (Dostalova et al., 2012).

There are several identification methods; the analysis of fingerprints is the most used when the tissue is viable for handling. DNA analysis is also employed, but this technique that costs a lot time, appropriate laboratory and it cannot be performed when the material is very degraded. Forensic Dentistry, the use of dental records to identify a person is a reliable, practical, fast and cheap identification method (Serra, Herrera & Fernandes, 2012; Serra et al., 2014; Xavier et al., 2015). In this context, image exams, as radiographies and computed tomographies (CTs), can be a worth source of information, for human identification (Gioster-Ramos et al., 2021). Therefore, Silva et al. (Silva et al., 2021) highlighted the possibility of achieving positive human identification with precision, only with the contribution of a single tooth. Palatal rugoscopy is also an important technique for human identification, employed by Forensic Dentistry (Santos, Fernandes & Serra, 2011; Manganotti et al., 2021).

Putrefied, skeletonized or charred bodies, especially in mass accidents, usually need identification, requiring the use of anthropological methods (Singh et al., 2013). The skull, pelvis and femur are the bones widely used in the sex estimation phase; however, in cases of trauma and accidents, hardly all these bone structures are found. The frontal sinus cavities, due to their resistance to damage, are very useful, as they are structures that are often protected, due to their resilience (Cox et al., 2009). There are no two individuals with identical frontal sinuses. In this way, it becomes a reliable comparative method of forensic interest for human identification (Caputo et al., 2011; Gadekar et al. 2019; Gioster-Ramos et al., 2021).

The evaluation of the frontal sinuses, even in monozygotic and dizygotic twins, shows that they have unique patterns, as well as being stable throughout life in all individuals. Thus, the reliability of comparing images, whether radiographic or from Computed Tomography (CT), ante and post-mortem of the frontal sinus for identification is valid (Trevelin & Lopez, 2012). This analysis is possible because it is a structure commonly exposed in medical and dental investigations. Thus, frontal sinus patterns have the potential to be used for personal identification, age estimation, and sexual dimorphism (Cox et al., 2009).

This work evaluates the possibilities of human identification using frontal sinuses 2D and 3D images and the role of orthodontists in this context.

2. Methodology

This article was based on a descriptive literature review with a qualitative approach (Pereira et al., 2018), constituting a broad study, allowing the inclusion of experimental and non-experimental research, of theoretical and empirical literature, in order to deepen the knowledge on the studied subject. A comprehensive search was carried out in the primary databases: PubMed, SciELO, LILACS and Web of Science. The descriptors used were "forensic dentistry", "frontal sinus", "orthodontics", "human identification", "cone beam computed tomography" and "three-dimensional images".

Initially, the search for descriptors was carried out individually and later crossings were made between them. For sample selection, articles, dissertations and theses that were available in full, published in Portuguese or English, in any period of time concerning the studied issue were included. The exclusion criteria were texts published in languages other than English and Portuguese and those that were not related to the studied topic. The search was classified and evaluated, ending with the interpretation of results and summary of knowledge.

This paper also has a theoretical and reflexive approach, carried out from the reading of Brazilian legislation regarding dental records and of imaging exams used by orthodontists.

3. Frontal Sinuses

The frontal sinuses are contained within the frontal bone, in the upper part of the superciliary arch, and consist of two air-filled cavities originating at the root of the nose and from the upper expansion in the peri-glabellar region. They are usually present in pairs - each one develops separately, there is a septum, that is most cases is deviated from the midline (Cossellu et al., 2015; Oliveira et al., 2020). Occasionally, one or both sinus may be absent. The prominence of the superciliary arches does not indicate the absence, presence or size of the frontal sinus. In some cases, the sinus may be overlapped in front of the other (Pondé et al., 2008).

These structures develop as diverticula from the lateral nasal wall, around the fourth fetal month after the development of the frontal recess (Michel et al., 2015), being visible until the end of the first year, and cannot be detected in a simple radiological film until 3 years old. They complete their development approximately at age 20, and remain stable throughout life (Michel et al., 2015). Tatlisumak et al.

evaluated 300 individuals using CT images to measure height, width and length of each frontal sinus and also the total width of each individual's sinuses. The authors verified that, in general, the highest values were observed in the age group of 31-40 years., with a tendency to decrease with time (Tatlisumak et al., 2008).

Among the rare changes that can affect this structure throughout life, causes such as tumors, fractures or infections can be mentioned (Goyal, etl a., 2013). However, the ability to identify remains using visual inspection of the frontal sinus is reported to be unaffected by the elapsed ante-mortem and post-mortem time (Cox et al., 2009). Its patterns are considered unique and its conformation proves to be highly individualized, in addition to showing itself as a powerful marker of personal identification (Michel et al., 2015). The uniqueness of its morphology is supported by the discovery of the differentiation of these structures even in monozygotic twins (Cox et al., 2009; Besana & Rogers, 2010; Trevelin & Lopez, 2012).

When dealing with the forensic situation, frontal sinus resilience becomes useful. Such a structure can be readily recovered intact with all its internal configuration preserved due to its intrinsic bone part and arched nature, which protects it from damage and decomposition, being convenient in cases of victims who were carbonized (Besana & Rogers, 2010; Silva et al., 2019).

4. Human Identification by Frontal Sinuses Analyses

Identification methods are comparative methods, i.e., it is necessary a first register of a known person to compare to a second register (of the deceased individual) of the analysed feature (Fernandes et al., 2013; Kuhnen et al., 2021; Barros et al., 2021). In forensic anthropology, the use of radiographic images of the frontal sinuses for human identification has been increasingly applied. The widespread use of conventional radiographs can be attributed to the fact that They are an inexpensive acquisition method, commonly available and practical for evaluating bone structures. They have the advantage of being well publicized and accessible, commonly used in cases of comparative identification processes (Goyal, etl a., 2013; Soares et al., 2016).

Radiological images of frontal sinuses are considered complementary exams in identification processes; a morphometric comparison of the frontal sinuses is performed, comparing shapes, size, symmetry, external borders and the presence of septa and cells in the images available by using radiographs and or CT scans before and post-mortem (Quatrehomme et al., 1996; Caputo et al., 2011; Franco et al., 2020; Gioster-Ramos et al., 2021).

The comparison of antemortem and postmortem radiographs of the frontal sinus can be done in an overlapping way or through coding systems. However, the overlapping of images has been questioned, since it requires images obtained with the same parameters at both times, despite being a technique accepted as reliable (Cossellu et al., 2015).

The use of dental radiographs, such as intraoral radiographs, panoramic radiographs and CT, has become quite common and routine in forensic cases, to obtain human identification (Gruber & Kameyama, 2001; Wood, 2006). CT is the recommended exam to perform the study of paranasal sinus morphology, due to its advantages, as: higher resolution, without overlapping elements, provision of three-dimensional scanning of these components, in addition to allowing precise and exact measurements (Tucunduva & Freitas, 2008; Uthman et al., 2010).

According to several authors, CT is the imaging technique used in the analysis of frontal sinuses (Tatlisumak et al. 2007; Tatlisumak et al., 2008; Tucunduva & Freitas, 2008; Uthman et al., 2010). Although the two types of CT (traditional and cone beam computed tomography -CBCT), allow images to be obtained in sections of the dentomaxillofacial region, the use of CBCT has created new opportunities for obtaining images. When compared to multislice acquisition, CBCT presents lower doses of radiation, low cost, high resolution and short exam duration, in addition to allowing the visualization of axial, coronal, sagittal and oblique images, as well as three-dimensional reconstruction (Garib et al., 2007; Buscatti, 2009). Thus, the use of images produced from 3D CBCT has become popular in the different specialties of Dentistry (Buscatti, 2009).

The posteroanterior radiographs (AP) of the skull are very useful in the clinical course, identifying trauma or pathologies in the frontal sinuses. However, such images can also allow the visualization of the morphology of these structures, helping in cases of human identification (Silva et al., 2008).

As the frontal sinus presents differences in shape, area and symmetry and may be absent in only 4% of the population, this becomes an important parameter both for the classification of sexual dimorphism and human identification. In view of this, it is extremely important that the images obtained by PA skull radiographs are made using the method employed correctly, and within the appropriate parameters of elaboration (Camargo, 2000; Riepert et al., 2001; Wood, 2006).

Hashim et al. (Hashim et al., 2015) when analyzing ante-mortem and post-mortem radiographs of two real cases and 12 simulated ones by overlap, found that the overlap of two frontal sinus radiographic patterns derived from the same skull only leads to a perfect overlap when orientation of the skull obtained in the first recording (simulated ante-mortem) is unchanged for the second (simulated post-mortem recording). Two problems were raised: 1. two 2D images are not superimposed even if they are derived from the same three-dimensional source; 2. the overlapping of two images in transparency would create a mixed third, leading to an illusion of compatibility.

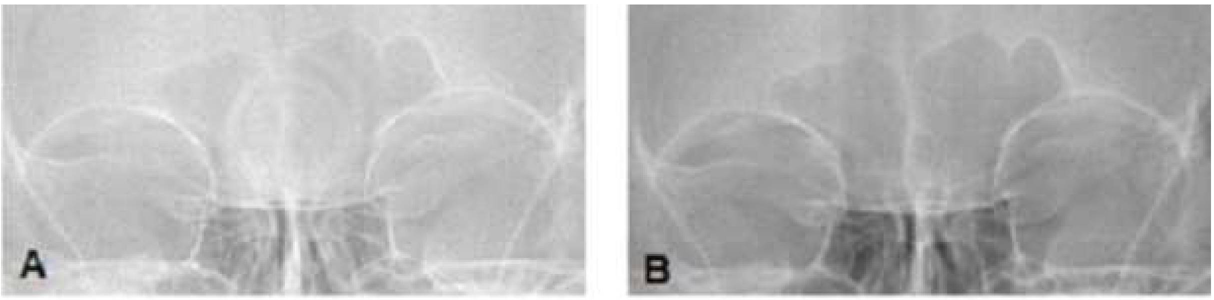
Silva et al. (Silva et al., 2009) employed, on an identification case, the image comparison and direct measurement methods on posteroanterior (PA) radiographs, according to the parameters recommended by Ribeiro (Ribeiro, 2000). This method consists on measuring five reference lines in X-ray images, in which the first is drawn through the upper edge of the orbits and the others are drawn perpendicular to the first line, from the following points: the outermost point of the right frontal sinus; the outermost point of the left frontal sinus; the highest point of the right frontal sinus; and the highest point of the left frontal sinus. By associating the data obtained in the anthropological investigation and in the dental exam, it was possible to identify the individual.

Nikam et al. (Nikam et al., 2015) evaluated PA radiographs of 109 adult individuals (above 20 y.o.), excluding people who suffered trauma or had a pathology that affected the frontal sinus and those who did not have such structure. In their research, they demonstrated that both the maximum height and the maximum width of the frontal sinus were found as a unique characteristic for each of the subjects.

An effective comparison between ante and postmortem data in identification processes, depends on the quantity and quality of the information provided by dental records (Rothwell, 2001; Serra, Herrera & Fernandes, 2012). It is important that dentists document well and keep their patients' clinical data (Serra et al., 2012; Serra et al., 2014). In particular orthodontists must, in addition to filling out clinical documents, keep all imaging exams of their patients, which may be essential in cases of human identification. As an example, frontal teleradiographies and CBCTs can be very helpful in these situations.

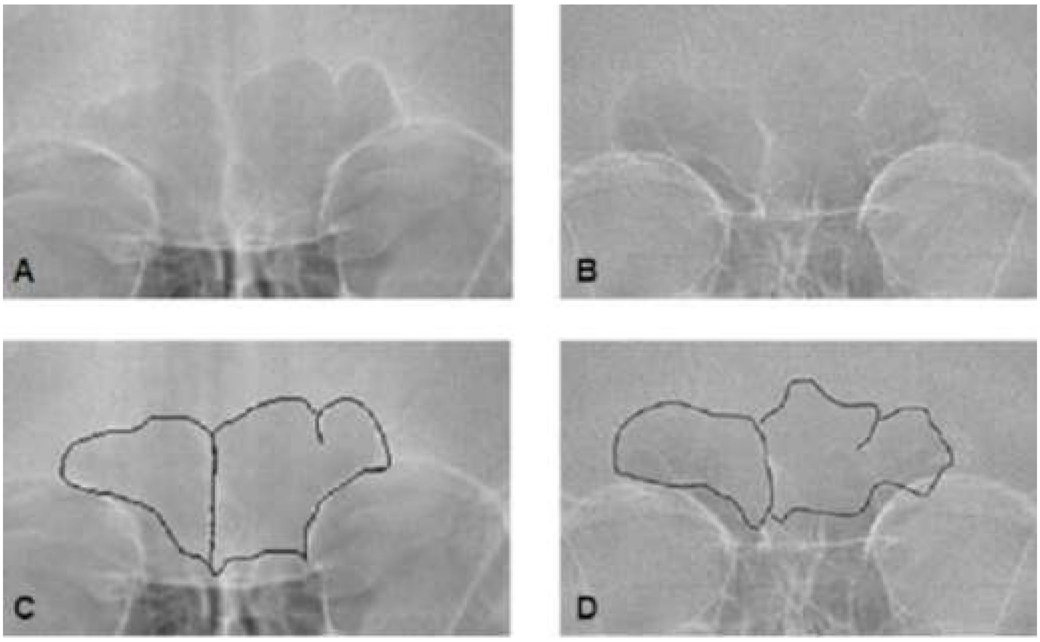
Figure 1 shows two frontal teleradiographies of the same individual, taken with an interval of 2 years. Figure 2 presents frontal teleradiographies of two different individuals, with and without the frontal sinuses highlighted.

Figure 1 - Frontal teleradiographies of the same individual, taken with an interval of 2 years. A. First image. B. Second image.



Source: Personal files of. Fernandes and Serra.

Figure 2 - Frontal teleradiographies of two different individuals. A. Individual A. B. Individual B. C. Frontal sinus of individual A highlighted. D. Frontal sinus of individual B highlighted.



Source: Personal files of. Fernandes and Serra.

According to the Brazilian Dental Code of Ethics (Conselho Federal de Odontologia, 2012), it is duty of the dentists:

Art. 9, X: elaborate and keep updated the dental records, according to current legislation, including the digital records;

Article 17 states:

Art. 17. It is mandatory the elaboration and maintenance of legible and updated dental records and keeping them in proper physical or digital files.

Imaging exams and plaster models, among others, are complementary data from orthodontic treatment and are part of the dental records, clinically assisting the orthodontist in monitoring completed or ongoing treatments (Silva et al., 2011). In addition, these documents contribute to Forensic Dentistry due to issues related to the professional liability and in the processes of identifying cases of skeletonized, putrefied or charred bodies (Silva et al., 2005; Silva et al., 2009; Serra, Herrera & Fernandes, 2012; Serra et al., 2014; Andrade et al., 2021).

5. Discussion

The employment of imaging exams in human identification is increasing day by day, although its use in Forensics depends on the availability of an antemortem exam. Radiographs are the most studied and publicized imaging exam; they have great applicability even nowadays, as they consist on a routine examination, guaranteeing the antemortem and postmortem data comparation (Goya et al., 2013; Cossellu et al., 2015; Soares et al., 2016).

Computer tomography provides a good opportunity to assess frontal sinuses with a three-dimensional approach and great precision in all measurements (Cappabianca et al., 2013). A significant advance in radiology is shown and is increasingly available and gradually replacing conventional radiographs, as they have several advantages over them, such as the non-overlapping of structures beyond the chosen visual field, allowing the visualization of small differences in density. It allows not only the visualization of its internal structure, as well as its shape in relation to size, bilateral distribution and format (Carvalho et al., 2009; Uthman et al., 2010); internal points for evaluation can be easily shown by segmenting the image. Craniometric points can be located with precision and more accurate measurements than in conventional radiographs. Thus, volumes and areas can be determined (Carvalho et al., 2009).

Frontal sinus CT has replaced radiographs in routine medical practice. Studies have shown that the use of CT for morphometric investigations on the frontal sinus is easy and reliable for ante-mortem/post-mortem comparisons (Emirzeoglu et al., 2007; Tatlisumak et al., 2008). Three-dimensional reconstructions are an important part of virtual anthropology and have been dramatically increased for qualitative and quantitative morphological analysis (Jun et al., 2010). It is noteworthy that the three-dimensional images may represent the size and shape of the overlap with the antemortem radiographs (Pfaeffli et al., 2006).

Michel et al. (Michel et al., 2015) believe that three-dimensional reconstructions of the frontal sinus provide more reliable data (e.g.: volume) than two-dimensional measurements. The "size" of an anatomical structure such as the frontal sinus should, whenever possible, be assessed using three-dimensional measurements.

Cone Beam Computed Tomography presents technical features such as relatively low dosages, high quality and bone definition; its compact design have been attractive for intraoperative scanning of frontal sinuses. Its portability makes it ideal for use in the field (Pfaeffli et al., 2006).

Although the analysis of frontal sinuses is traditionally carried out using two-dimensional images, there is a growing trend of studies employing CT scans. Cone-Beam Computed Tomography is an important diagnosis tool, more frequently used in orthodontics, which allows a three-dimensional approach and great precision in measurements.

Improvements in three-dimensional radiographic techniques have generated a lot of data that can also be used for identification purposes. In comparison with traditional two-dimensional techniques, three-dimensional images yield more accurate and reliable information, such as volume assessment (Kim et al., 2013).

In certain cases, the analysis of frontal sinus measurements makes possible to determine sexual dimorphism, either by analyzing the measurements of its area or its volume, where the males present higher values than the females, in general (Tatlisumak et al., 2008; Michel et al., 2015). Uthman et al. demonstrated that by adding craniometric measurements to the frontal sinus patterns, greater precision is obtained in determining sex (Uthman et al., 2010). Nevertheless, Xavier et al. (Xavier et al., 2015) and Goyal et al. (Goyal et al., 2013) reported that the frontal sinus has limited application as only sex predictor, even though it is effective for identification. For this purpose, it should be used only when other parameters are not effective.

Maxillofacial imaging exams can be used as antemortem records for forensic analysis. Concerning frontal sinus images, frontal teleradiographies and CBCTs are of great value. As these exams can be part of orthodontical records, it is very important that orthodontists are aware of the forensic importance and application of these imaging exams, and keep them properly.

Identification methods are comparision methods; it is necessary to have a suspicion about the identity of the individual, and ask the family to provide his/her antemortem data. In this context, orthodontic imaging exams, if available, can be fundamental. They can even be the only identification possibility, before thinking on DNA analysis (which takes more time to be performed and is much more expensive than imaging comparison).

6. Conclusion

The frontal sinus radiographic analysis is a useful tool for human identification, as it usually provides a high degree of precision. Together with two-dimensional analysis of frontal sinuses, 3D images are of great value for human identification. Although three-dimensional analysis is not yet a routine, its use in Forensics is undoubtedly an excellent tool provided by new technologies. Therefore, it is important that orthodontists know this possibility, be aware of the importance of imaging exams in Forensics, and properly keep their patients' imaging records.

In Forensics, digital methods use to be fast, efficient and objective. Additional research must be carried out in order to create standardized protocols using new technologies, especially 3D analysis of frontal sinuses. This would improve the work of Forensic experts, helping Justice and Society.

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3.3 Publicação 3[3*]

Three-dimensional analysis of the maxillary sinus according to sex, age, skin color, and nutritional status: a study with live Brazilian subjects using cone-beam computed tomography[1]

Abstract

Objective: To perform three-dimensional measurements (volume and area) of the maxillary sinus (MS), from cone-beam computed tomography (CBCT) images, and to assess potential differences between the left and right sides and a correlation of the measurements to sex, age, skin color, and nutritional status.

Design: CBCT images of 161 living Brazilian subjects of both sexes (89 women and 72 men) were used, and three-dimensional measurements of volume and area were made with the beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland). The inter- and intra-examiner reproducibility of measurements was evaluated with TEM, rTEM, and R.

Results: Both MS volume and area did not show significant differences between the left and right sides and between the sexes. Volume and area were significantly lower in the age group from 6 to 11 years than in the other two groups ($p<0.05$). The measurements obtained for MS volume and area were significantly higher in white individuals ($p<0.05$), but they did not show significant differences ($p>0.05$) regarding nutritional status (considering the body mass index - BMI).

Conclusion: There were no statistically significant differences between the sexes, which does not allow recommending the use of MS volume and area measurements to analyze sexual dimorphism, and the same occurs for BMI. However, such measures can help to estimate the age and skin color of individuals.

Keywords: Human identification; Maxillary sinus; Cone-Beam Computed Tomography; 3D images; Forensic anthropology; Forensic dentistry.

1. Introduction

[3*]Artigo em revisão e descrito segundo as normas do periódico *Archives of Oral Biology*.

[1] O material e métodos deste estudo foram obtidos do trabalho de tese de doutorado da própria autora.

The identification process is complex, systematic, and organized, with the main objective of returning the identity to an individual. This identity is a set of physical, functional or psychological, and normal or pathological characteristics that qualify the individual as identical only to himself (Nikam et al., 2015; Xavier et al., 2015). Although highly significant, this is a challenging task for humankind because it deals with humanitarian issues and presents direct implications in civil and criminal proceedings (Dostalova et al., 2012).

Identification methods are objective because they lead to the identity of individuals based on scientific data, and they are required for living individuals and cadavers, cadaver remains, bones, and even objects, weapons, and clothing. These methods are comparative and, in case of death, they establish a judgment of comparison between the data before death (*ante-mortem* data) and the data after death (*post-mortem* data). Therefore, if suspected that the body found is from a particular individual, the *ante-* and *post-mortem* data must be compared to establish an identity (Fernandes, 2010; Rissech, 2003).

Considering the particularities of their contours, analyzing paranasal sinuses is valuable for human identification for providing information and reducing the risk of errors by forensic professionals during investigations (Barros et al., 2021a; Gioster-Ramos et al., 2021; Musse, 2009).

Several studies have evaluated maxillary sinus, frontal sinuses, and sphenoid sinuses to identify individuals (Musse, 2009; Perella et al., 2003; Tatlisumak et al., 2008; Uthman et al., 2010), using extraoral radiographs (Pfaefflli et al., 2007; Riepert et al., 2001; Silva et al., 2009) and CT scans (Perella et al., 2003; Pfaeffli et al., 2007; Tatlisumak et al., 2008; Uthman et al., 2010). Such structures were also studied to analyze sexual dimorphism, age, and ancestry (Araujo et al., 2015; Camargo, 2000; Demiralp et al., 2019; Etemadi et al., 2017; Farias Gomes et al., 2019; Garcia, 2014; Moore & Ross, 2017; Najem et al., 2020; Özer et al., 2018; Rani et al., 2017; Robles et al., 2020; Saccucci et al., 2015; Sidhu et al., 2014), among others. Currently, computed tomography allowed a three-dimensional analysis, which optimizes and enhances the resources available to Forensic Sciences to assist Justice and society in the search for human identification in real cases (Scarfe et al., 2006).

The radiographic images of maxillary sinus for human identification may be a complementary exam that provides relevant data to the expert investigation with standardized methodologies. For identification, a morphometric comparison of the sinuses is made concerning the shape, size, and contour of the images available, because visualizing the contours of this structure defines an identity with precision (Pfaeffli et al., 2007).

This study aimed to perform three-dimensional measurements of maxillary sinus volume and area from Brazilian individuals' cone-beam computed tomography (CBCT) images and to assess potential differences between the left and right sides and a correlation between the measurements to sex, age, skin color, and nutritional status. There are few published data concerning three-dimensional maxillary sinuses measurements using CBCT, specially concerning Brazilian population. In addition to the few publications, this is the first study that evaluates the influence of skin color and nutritional status on maxillary sinus volume and area. This study is providing significant new insights as well as being on another (Brazilian) population.

2. Materials and Methods

2.1 Ethics and study sample

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University - Unesp (CAAE - nº 47706121.4.0000.5416).

The sample consisted of head and neck CBCT images of 161 living Brazilian subjects of both sexes (89 women and 72 men) from an image bank owned by one of the researchers. Images of maxillary sinus showing changes due to malformations, obliterations, pathologies, and/or trauma were not included. The identity of the individuals remained confidential. The variables of sex, age, skin color, and nutritional status were considered, hence, the body mass index (BMI) was used. However, some information was not available for the entire sample.

The following age groups were considered: from 6 to 11 years (n=37), 12 to 17 years (n=52), and 18 years or older (70 adults). Regarding skin color, there were 120 white individuals and 37 black individuals. The BMI was calculated with the following formula: BMI = weight/height^2. Thirty-seven individuals had a normal BMI (between

18.5 and 24.9), and 44 had a BMI above normal (above 25) (Telehealth National Program Brazil Networks).

The maxillary sinus was measured on both sides (right and left). However, when a sinus presented some pathology, the other one was measured.

2.2 Three-dimensional digital measurements of volume and area

The three-dimensional volume and area measurements were made with a beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland) and CBCT images in DICOM (Digital Imaging and Communications in Medicine) format.

In the “Airways” option of the “Point tools”, the following parameters were used to define the maxillary sinus in the sagittal, axial, and coronal planes (Figure 1): Blocker radius: 10.00; Difference from: -300; Difference to: 300; Maximal opening diameter: 2.00.

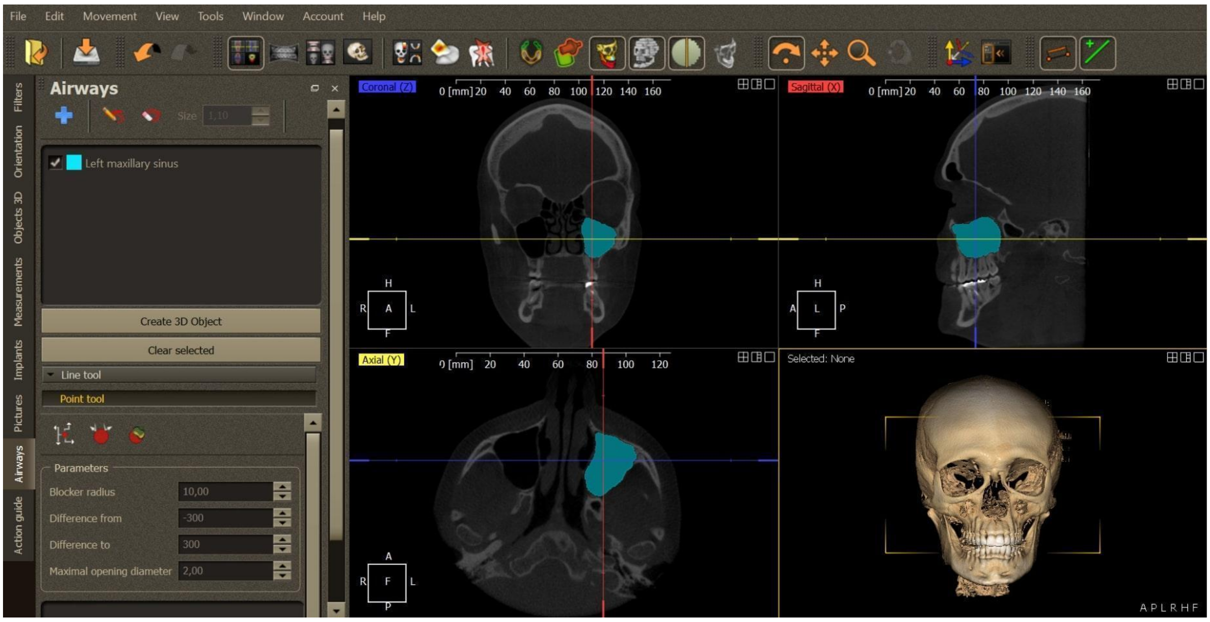

Figure 1. Delimitation of a maxillary sinus in the axial, sagittal and coronal planes, using DDS-Pro™ software. The employed parameters of the tool “point tools” (Blocker radius: 10.00; Difference from: -300; Difference to: 300; Maximal opening diameter: 2.00) are visible on the lower left side of the image.
Source: Own elaboration.

After defining the sinuses in the three planes, a three-dimensional reconstruction of the maxillary sinus was performed, in which volume and area measurements were made (Figure 2).

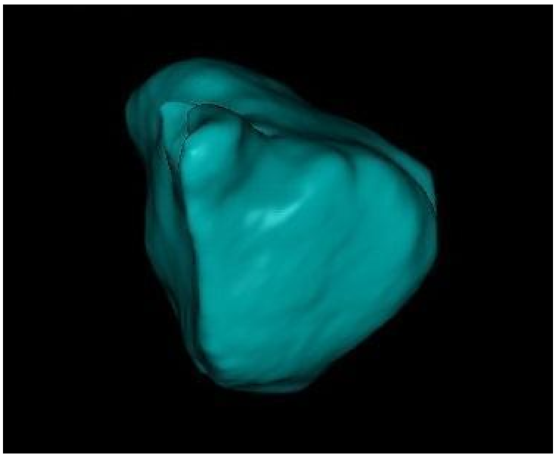

Figure 2. Three-dimensional volumetric image of a left maxillary sinus, obtained from a cone-beam computer tomography, using DDS-Pro™ software.
Source: Own elaboration.

2.3 Statistical analysis

Initially, descriptive analyses of the sample profile variables were performed with absolute and relative frequencies. The inter- and intra-examiner reproducibility of measurements was evaluated with TEM (technical error of measurement), rTEM (relative technical error of measurement), and R (coefficient of reliability). Descriptive and exploratory data were then analyzed, and generalized linear models were used to analyze the left and right sides relative to maxillary sinus area and volume, considering, in the model, the dependence between the sides of the same participant. The means of the left and right sides of each participant were calculated and a new descriptive and exploratory analysis was performed for these means. Generalized linear models were used to analyze sex, age group, skin color, and body mass index relative to volume and area. The measurement means were also estimated with the respective 95% confidence intervals for sex and age group. All analyses were performed with the R software at a 5% significance level (R Core Team, 2021).

3. Results

Table 1 shows that 55.3% of the sample were female and 44.7% were male. Also, 43.5% were18 years or older, 23.0% were to 11 years old, and 32.3% were 12 to 17 years old. The skin color of 74.5% of the sample was white.

Table 1. Profile of the sample studied (n=161).

Variable	Category	Frequency (%)
Sex	Female	89 (55.3%)
	Male	72 (44.7%)
Age group (years)	From 6 to 11	37 (23.0%)
	From 12 to 17	52 (32.3%)
	18 or older	70 (43.5%)
	No information	2 (1.2%)
Skin color	White	120 (74.5%)
	Black	37 (23.0%)
	No information	94 (2.5%)
BMI	Normal	37 (23.0%)
	Above normal	44 (27.3%)
	No information	80 (49.7%)

BMI – Body mass index.

Table 2 presents the results of the analyses of measurement reproducibility (intra- and inter-examiner). The intra-examiner TEM was 12.2 mm^2 for the maxillary sinus area and 204.9 mm^3 for volume. The intra-examiner rTEM was 0.38% and 1.7% for area and volume, respectively. The R values were very close to one, indicating excellent measurement accuracy. The inter-examiner TEM was 13.7 mm^2 and 145.2 mm^3 for area and volume, respectively. The inter-examiner rTEM was 0.43% and 1.2% for area and volume, respectively. The inter-examiner R values were very close to one.

Table 2. Results of the analyses of inter- and intra-examiner errors in measurements (n=30).

Variable	**Intra-examiner**			**Inter-examiner**		
	TEM	**rTEM**	**R**	**TEM**	**rTEM**	**R**
Maxillary sinus area	12,239	0,384	1,000	13,719	0,430	1,000
Maxillary sinus volume	204,959	1,723	0,998	145,150	1,219	0,999

TEM: technical error of measurement; rTEM: relative technical error of measurement; R: coefficient of reliability.

The left side presented higher values, but there was no significant difference between the sides of the individuals regarding maxillary sinus area and volume (p>0.05) (Table 3). Men showed higher values than women for both measures, but there was no significant difference between the sexes (p>0.05) (Table 4). However, both maxillary sinus area and volume were significantly lower in the age group from 6 to 11 years than in the other two groups (p<0.05) (Table 5 and Figures 3 and 4).

Table 3. Results of the analyses of sides comparisons.

	Side				Difference between the sides		[1]p-value
	Left		Right				
Variable	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus area (mm^2)	2.950,21 (988,43)	2.899,90 (708,01; 6.575,39)	2.883,66 (1.010,18)	2.899,57 (453,19; 5.981,73)	66,56,00 (463,95)	60,55 (-1.105,55; 2.096,63)	0,3225
Maxillary sinus volume (mm^3)	10.526,79 (4863,45)	9.841,40 (1.130,92; 29.718,40)	10.245,31 (5.716,39)	9.723,76 (743,10; 43.564,00)	281,48 (4.378,03)	389,44 (-35.048,85; 7.281,89)	0,4367

[1]Generalized linear model.

Table 4. Results of the analyses of sexes comparisons.

Variable	Sex				[1]p-value
	Female		Male		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus area (mm²)	3.016,29 (835,54)	2.981,02 (994,03; 5.811,26)	3.310,49 (1.126,65)	3.068,28 (805,77; 6.257,40)	0,0655
Maxillary sinus volume (mm³)	10.940,38 (4.253,80)	10.669,00 (2.259,55; 2.609,58)	11.995,30 (5.482,60)	10.829,88 (1.585,89; 26.956,40)	0,1833

[1]Generalized linear model.

Table 5. Results of the analyses of age group comparisons.

Variable	Age group (years)						[1]p-value
	6 to 11		12 to 17		18 and older		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus area (mm²)	2,583.03 (694.82) B	2,621.03 (1,223.06; 4,735.98)	3,131.34 (871.97) A	3,023.13 (994.03; 6,257.40)	3,474.33 (1,059.13) A	3,444.44 (805.77; 5,915.56)	<0.0001
Maxillary sinus volume (mm³)	8,543.92 (3,143.38) B	8,560.61 (2,956.47; 16,776.10)	11,411.38 (4,552.50) A	10,678.83 (2,259.55; 2,6956.40)	13,002.56 (5,148.19) A	12,329.65 (1,585.89; 26,039.58)	<0.0001

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups (p≤0.05).

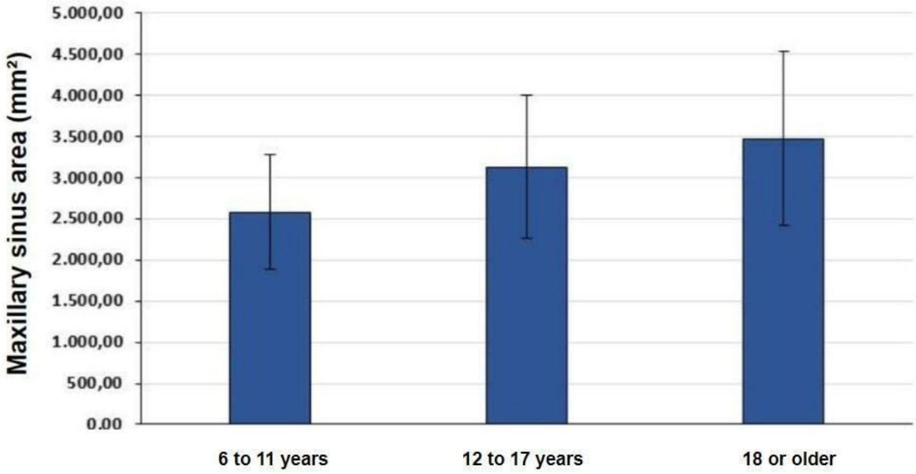

Figure 3. Mean (standard deviation) of the maxillary sinus area (mm2) regarding age groups (6-11 y.o.; 12-17 y.o. and 18 y.o. or older).

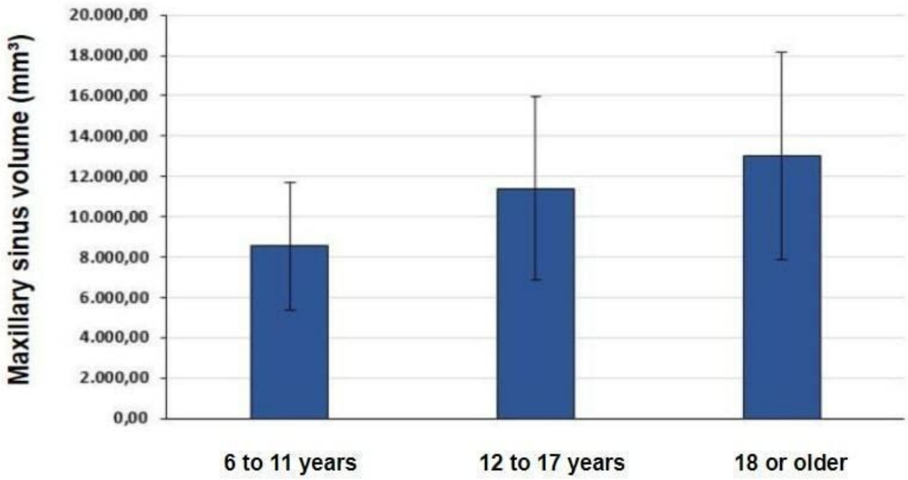

Figure 4. Mean (standard deviation) of maxillary sinus volume (mm3) regarding age group (6-11 y.o.; 12-17 y.o. and 18 y.o. or older).

Table 6 and Figures 5 and 6 also show that both maxillary sinus area and the volume were significantly higher in white participants ($p<0.05$).

Table 6. Results of the analyses of skin color comparisons.

Variable	Skin color				[1]p-value
	White		Black		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus area (mm^2)	3.237,03 (956,97) A	3.079,15 (934,35; 6.257,40)	2.860,15 (1.025,29) B	2.864,86 (805,77; 5.714,77)	0,0408
Maxillary sinus volume (mm^3)	11.832,42 (4.733,18) A	11.092,10 (1.969,08; 2.6956,40)	9.987,96 (4.917,37) B	10.020,70 (1.585,89; 25.579,60)	0,0406

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups (p≤0.05).

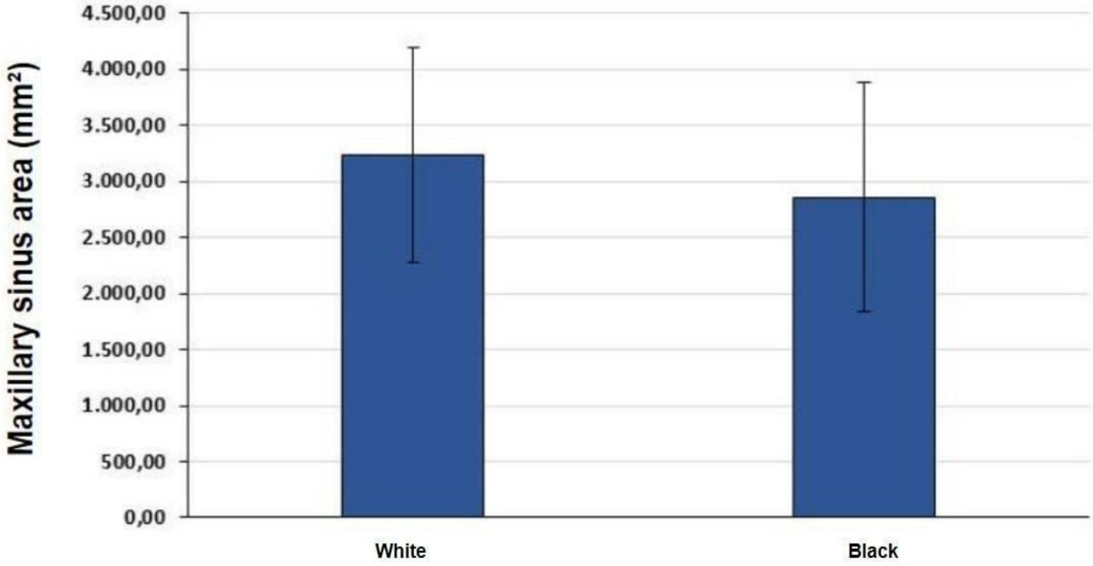

Figure 5. Mean (standard deviation) of the maxillary sinus area (mm2) regarding skin color (black and white subjects).

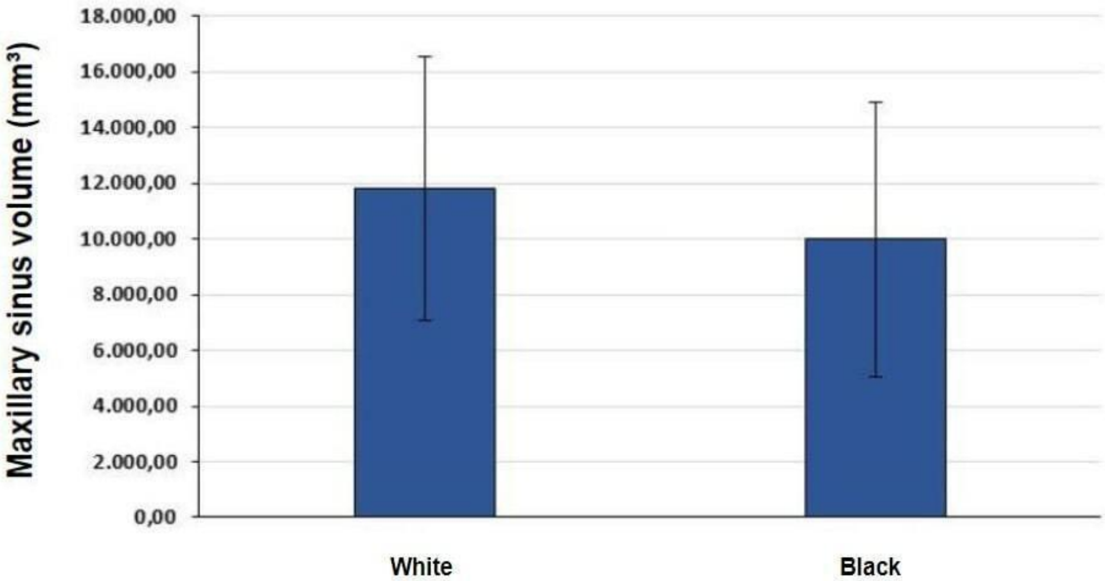

Figure 6. Mean (standard deviation) of maxillary sinus volume (mm3) regarding skin color (black and white subjects).

There was no significant difference between the BMI categories (normal or above normal) regarding maxillary sinus area and volume ($p>0.05$) (Table 7).

Table 7. Results of analyses of BMI categories comparisons.

Variable	BMI				[1]p-value
	Normal		Above normal		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus area (mm^2)	3.274,70 (827,02)	3.140,66 (14.27,28; 5.495,87)	3.020,41 (1.024,47)	2.918,59 (934,35; 6.257,40)	0,2422
Maxillary sinus volume (mm^3)	11.706,93 (3710,14)	10.889,3 (3.886,09; 20.779,85)	10.572,41 (4.629,29)	10.089,93 (1.969,08; 26.956,40)	0,2617

[1]Generalized linear model. BMI = Body Mass Index.

Table 8 presents the estimation of maxillary sinus area and volume regarding sex and age group, with the respective 95% confidence intervals.

Table 8. Estimation of maxillary sinus area and volume for males and females according to age groups.

Variable	Sex	Age group (years)					
		6 to 11		12 to 17		18 and older	
		Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%
Maxillary sinus area (mm^2)	Female	2.561,70 (609,25)	2.284,37 – 2.839,03	2.845,14 (720,13)	2.541,05 – 3.149,22	3.326,61 (873,42)	3.061,07 – 3.592,16
	Male	2.611,03 (813,81)	2.177,38 – 3.044,68	3.376,66 (926,93)	3.017,23 – 3.736,08	3.724,32 (1.296,34)	3.200,72 – 4.247,92
Maxillary sinus volume (mm^3)	Female	85.09,01 (2.921,37)	7.179,22 – 9.838,80	10.031,82 (3.681,68)	8.477,18 – 11.586,46	12.596,39 (4.433,70)	11.248,42 – 13.944,36
	Male	8.589,74 (3.511,54)	6.718,57 – 10.460,91	12.593,86 (4.945,64)	10.676,14 – 14.511,58	13.689,94 (6.209,48)	11.181,87 – 16.198,00

CI: Confidence interval

4. Discussion

Putrefied, skeletonized, or charred bodies, especially in mass accidents, usually require identification with anthropological methods (Singh et al., 2013). The skull, pelvis, and femur are the bones mostly used in the sex determination phase, but in cases of trauma and accidents, these skeletal structures are rarely found in their entirety. Therefore, sella turcica, mastoid cells, and paranasal sinuses can be used (Cox et al., 2009).

Paranasal sinuses are considered pneumatic cavities because they are composed of air and lined by a mucoperiosteal membrane covered by a ciliated cylindrical pseudostratified epithelium, establishing direct or indirect communication with the respiratory system. They can ensure harmony in facial growth and make the skull lighter, as well as protect infraorbital and intracranial structures in cases of injury, partially neutralizing the impact (Batista et al., 2011).

Considering the particularities of their contours, paranasal sinuses are useful to identify individuals because they provide information and reduce the risk of errors by forensic professionals during investigations (Barros et al., 2021a; Gioster-Ramos et al., 2021; Musse, 2009). Several studies have evaluated paranasal sinuses for human identification (Musse, 2009; Perella et al., 2003; Tatlisumak et al., 2008; Uthman et al., 2010), using extraoral radiographs (Pfaeffli et al., 2007; Riepert et al., 2001; Silva et al., 2009) and CT scans (Perella et al., 2003; Pfaeffli et al., 2007; Tatlisumak et al., 2008; Uthman et al., 2010).

Many studies have used maxillary sinus for identification (Abasi et al., 2019; Amin, Hassan, 2012; Akhlaghi et al., 2017; Bangi et al., 2017; Saccucci et al., 2015; Teke et al., 2007; Tunis et al., 2017; Uthman et al., 2011; Waluyo et al., 2020). The present study performed three-dimensional measurements (volume and area) of maxillary sinus and analyzed potential differences between the right and left sides and a correlation of the measurements to sex, age, skin color, and nutritional status. There are no studies in the literature including all these analyses to allow establishing comparisons with the data found in this study. There was also no data from other studies referring to the maxillary sinus area without obliterations or pathologies.

In anthropometry, Technical Error Measurement (TEM) is the most common way of expressing the margin of error, which is an indicator of accuracy and represents the dimension of measurement quality control (Barros et al., 2021b; Perini et al., 2005). The intra- and inter-examiner TEM and rTEM results obtained in this study, for both area and volume, show data reliability. For both analyses, the R values were very close to one, indicating excellent precision and reproducibility of the measurements and confirming their reliability.

This study did not show significant differences between the left and right sides for both area and volume. The mean maxillary sinus volumes obtained in this study were 10,245.31 mm^3 and 10,526.79 mm^3 for the right and left sides, respectively. Aktuna Belgin et al. (2019), using CBCT images of 200 Turkish subjects, found a mean volume of the right and left maxillary sinus of 14.49 ± 3,998 cm^3 and 14.59 ± 3,984 cm^3, respectively, showing no statistically significant differences between right and left maxillary sinus volume. Gulec et al. (2020), studying a sample of Turkish individuals, found 13,173 mm^3 for the right side and 13,194 mm^3 for the left side. Sahlstrand-Johnson et al. (2011), performed with a sample of 60 Swedish individuals, did not show statistically significant differences between the estimated volume of the right (15.3 cm^3) and left (15.5 cm^3) maxillary sinus.

Similar to our findings regarding volume measurements, Farias Gomes et al. (2019), Teixeira et al. (2020) and Waluyo et al. (2020) also did not find statistically significant differences between the sides. However, Bangi et al. (2017), studying volumetric measures of maxillary sinus of 100 Indians, found statistically significant differences for sex and between the right and left sides. The authors observed larger dimensions in males and on the right side. The literature reports differences between populations (Fernandes, 2004), which shows the need for specific population data.

The present study did not find significant statistical differences between the sexes, similar to the studies by Gulec et al. (2020) and Saccucci et al. (2015), in which the authors verified that maxillary sinus volume was similar in men and women. However, other studies performed with different populations obtained statistically different values between the sexes (Aktuna Belgin et al., 2019; Bangi et al., 2017; Faria Gomes et al., 2019; Gamba et al., 2017; Rani et al., 2017;

Sahlstrand-Johnson et al., 2011; Sharma et al., 2014; Teixeira et al., 2020; Urooge, Patil, 2017), which differs from this study.

Regarding age, the sample in this study was classified into three age groups (06 - 11 years, 12 - 17 years, and 18 years or older). Both maxillary sinus area and volume were significantly lower in the 6-11 age range than in the other two groups ($p<0.05$), indicating that volumetric measurements of the sinus can be used to estimate age. Aktuna Belgin et al. (2019) established five age groups: 18–24 years, 25–34 years, 35–44 years, 45–54 years, and ≥ 55 years. The authors observed that maxillary sinus volume differed significantly between the groups. As the authors did not analyze data from individuals aged between 6 and 17 years, it is impossible to compare their findings with those of the present study. Rani et al. (2017) studied individuals aged between 21 and 73 years and found significant differences for maxillary sinus volume, which decreased with advancing age. However, it is impossible to establish comparative parameters with the present study, as the age groups do not correspond. However, Sahlstrand-Johnson et al. (2011), who studied only adults (ages 18 to 65 years), found no significant differences for age.

Considering the scarcity of investigations on age prediction, the findings of the present study may be a starting point for further investigations in this area.

As for skin color, both maxillary sinus area and volume were significantly higher in white participants than in black individuals ($p<0.05$). However, there was no significant difference between the BMI categories (normal or above normal) regarding maxillary sinus area and volume ($p>0.05$), evidencing the impossibility to confirm a relationship between the parameters measured with the available data.

So far there are no studies in the literature relating maxillary sinus measurements to skin color and BMI, which did not allow establishing comparative parameters.

5. Conclusion

There were no statistically significant differences between the sexes, which does not allow recommending maxillary sinus volume and area measurements to analyze sexual dimorphism, and the same occurs for nutritional status. However, such measures can help to estimate the age and skin color of individuals, as there were significant differences in these groups.

6. Ethical approval

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University (Unesp).

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9. Conflicts of interest

There are no conflicts of interest.

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3.4 Publicação 4[4*]

Maxillary sinuses' height/width/depth of Brazilian subjects and influence of sex, age, skin color, and nutritional status: a CBCT study[1]

ABSTRACT

To perform linear (two-dimensional) measurements of maxillary sinuses (MS) using cone-beam computed tomography (CBCT) images, analyze the influence of sex, age, skin color, and nutritional status (body mass index - BMI), and verify differences between the right and left sides. The sample consisted of CBCT images of 238 living Brazilian subjects (139 women and 99 men). Linear measurements of height, width, and depth of the right and left MS were performed with the DDS-Pro® 2.12.0_2021 software (DPP Systems, Czestochowa, Poland). All data were submitted to the statistical analysis to validate potential significant differences ($p>0.05$) for sex and age and correlation to skin color and BMI. The TEM, rTEM, and R were used for intra- and inter-examiner assessments. There were differences between the sides, with significantly higher measurements on the right side for MS height and on the left side for width and depth. The MS width was only greater ($p>0.05$) in men. Adult individuals (18 years or older) had higher MS height measurements than the other age groups. The measurements for skin color and BMI did not show significant differences, and it was impossible to confirm a relationship between the parameters measured. The measurements of MS height and width showed significant differences between the right and left sides and anatomic variability between the sexes for MS width, which can help analyze sexual dimorphism. There were also significant differences between the age groups. There was no significant difference in the measurements for skin color and nutritional status.

Keywords: Forensic imaging. Human identification. Maxillary sinus. Cone-Beam Computed Tomography. Forensic anthropology. Forensic dentistry.

Introduction

Anthropological methods are used when bodies are found and taken to the Legal Medical Institute without suspicions of their identities [1]. In this case, to assist

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[4*] Artigo revisão e descrito segundo as normas do periódico *Forensic Imaging.*

[1] O material e métodos deste estudo foram obtidos do trabalho de tese de doutorado da própria autora.

the identification process, analyzing the bones of the skull, pelvis, and femur, paranasal sinuses, among others, is convenient to determine individual characteristics [2].

From skeletal characteristics, the accurate characterization of sex is an essential step in forensic investigations [3,4], because sex estimation is one of the most important analyses in the forensic context [5]. For expert interpretations, age must be estimated to establish the civil and criminal age of majority, which has an important forensic function in the human identification of corpses [6]. Ancestry estimates are performed with morphological characteristics and skeletal measurements, which facilitate the compatibility with established ancestral groups [7].

Paranasal sinuses are structures arranged in both facial hemispheres and categorized according to their anatomical relationships into maxillary sinus (MS), ethmoid sinus (ES), frontal sinus (FS), and sphenoid sinus (SS) [8-10]. Considering the particularities of their contours, paranasal sinuses are valuable for human identification, as they provide information and reduce the risk of errors by forensic professionals during investigations [11-14].

Located in the maxillary bones, maxillary sinuses are the first to develop and the largest among paranasal sinuses [15]. The formation of MS starts in the 10th week of fetal development. From the 17th to the 20th week and the 25th to the 28th week, there is a rapid growth of MS [16]. At four years old, the sinus floor relates to the roots of first premolars and, at five years old, to second molars. It may extend to third molars and/or first premolars and sometimes to canines, appearing in a pyramid shape [17] with an alveolar process as the base and the orbit floor as the roof [18].

To visualize paranasal sinuses, different imaging tests are used, such as Waters and panoramic radiographs, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Cone-Beam Computed Tomography (CBCT). Due to its higher resolution, lower radiation, and lower cost, CBCT has recently become a suitable imaging method for analyzing sinuses [19,11]. Considering the characteristics of their contours along with the comparison between the data obtained with imaging methods, paranasal sinuses can provide information for forensic identification [11,20].

Regarding MS use, their characteristics provide relevant information that allows human identification [21-23], presenting high variability for CBCT detection of the craniofacial region, and favoring accurate human identification.

The literature presents data of linear MS measurements, especially from conventional radiographs, as CBCT use is still sporadic. Some studies correlate sex and age, but there is no information on the influence of skin color and nutritional status on linear MS measurements.

This study aimed to perform linear (two-dimensional) MS measurements in cone-beam computed tomography images of Brazilian living subjects, analyze the influence of sex, age, skin color, and nutritional status (body mass index - BMI), and verify differences between the right and left sides.

Material and methods

The present study used head and neck CBCT images of 238 living Brazilian subjects of both sexes (139 women and 99 men) between 6 and 68 years old. Besides sex, the study also considered variables of age, skin color, and nutritional status (with the body mass index - BMI). Some individuals in the sample did not have available information on all variables.

The BMI was calculated with the following formula: BMI = weight/height^2. The sample consisted of 58 subjects with normal BMI (between 18.5 and 24.9) and 61 with BMI above normal (above 25) [24]. As for skin color, 182 individuals were white, and 47 were black. The three following age groups were considered: 06 to 11 years (n=49), 12 to 17 years (n=69), and 18 years or older (n=118).

The images were obtained from an image bank owned by one of the researchers participating in this study. This project was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University - Unesp (CAAE - nº 47706121.4.0000.5416).

The sample did not include MS images with pathologies, obliterations, malformations, and/or trauma. The images selected were made available and used in DICOM (Digital Imaging and Communications in Medicine) format. The DDS-Pro®

2.12.0_2021 software (DPP Systems, Czestochowa, Poland) was used to obtain the linear measurements.

The MS height, width, and depth were measured in all images. Two examiners performed the three measurements at time intervals of at least seven days to verify reproducibility. Height and width were measured in coronal view, and depth was measured in sagittal view (Figures 1-2). The MS of the right and left sides of all individuals were measured. When one of the sinuses presented some exclusion factor, then only MS without changes were measured.

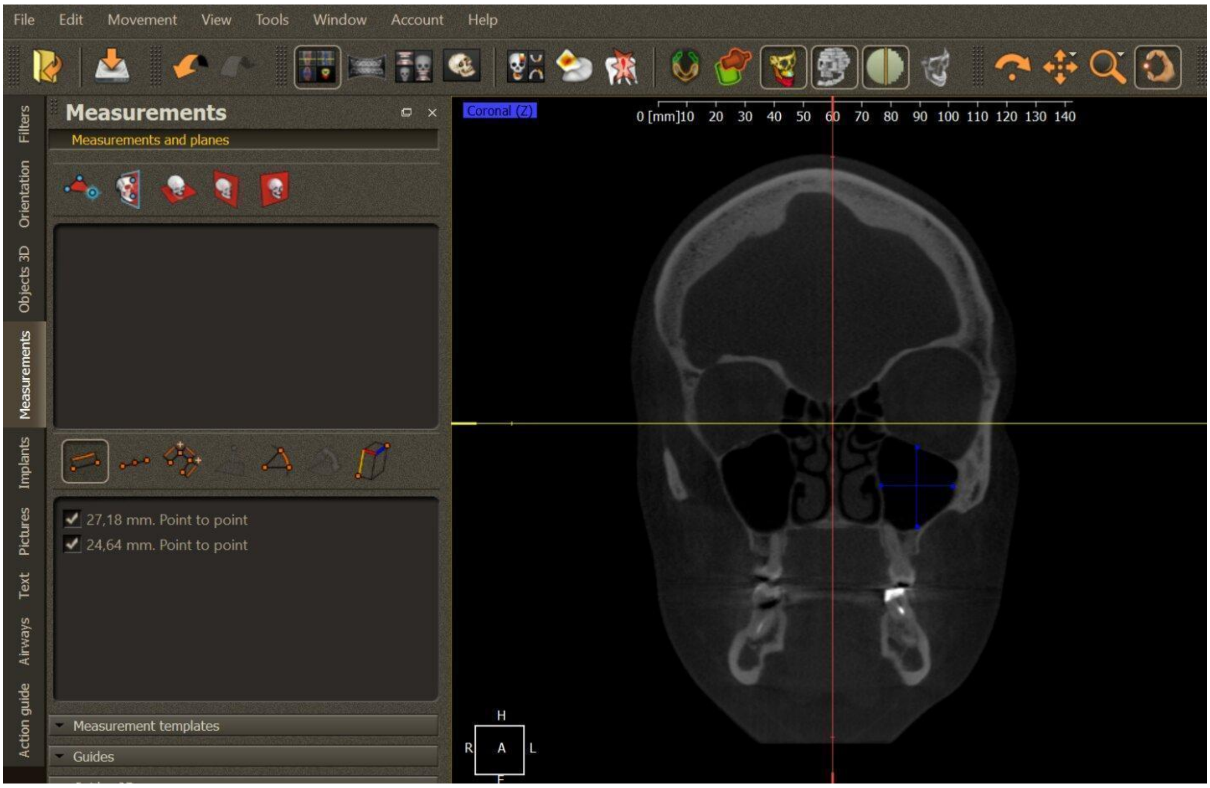

Fig. 1. Linear measurements (height and width) of a maxillary sinus in the coronal plane. Source: Own elaboration.

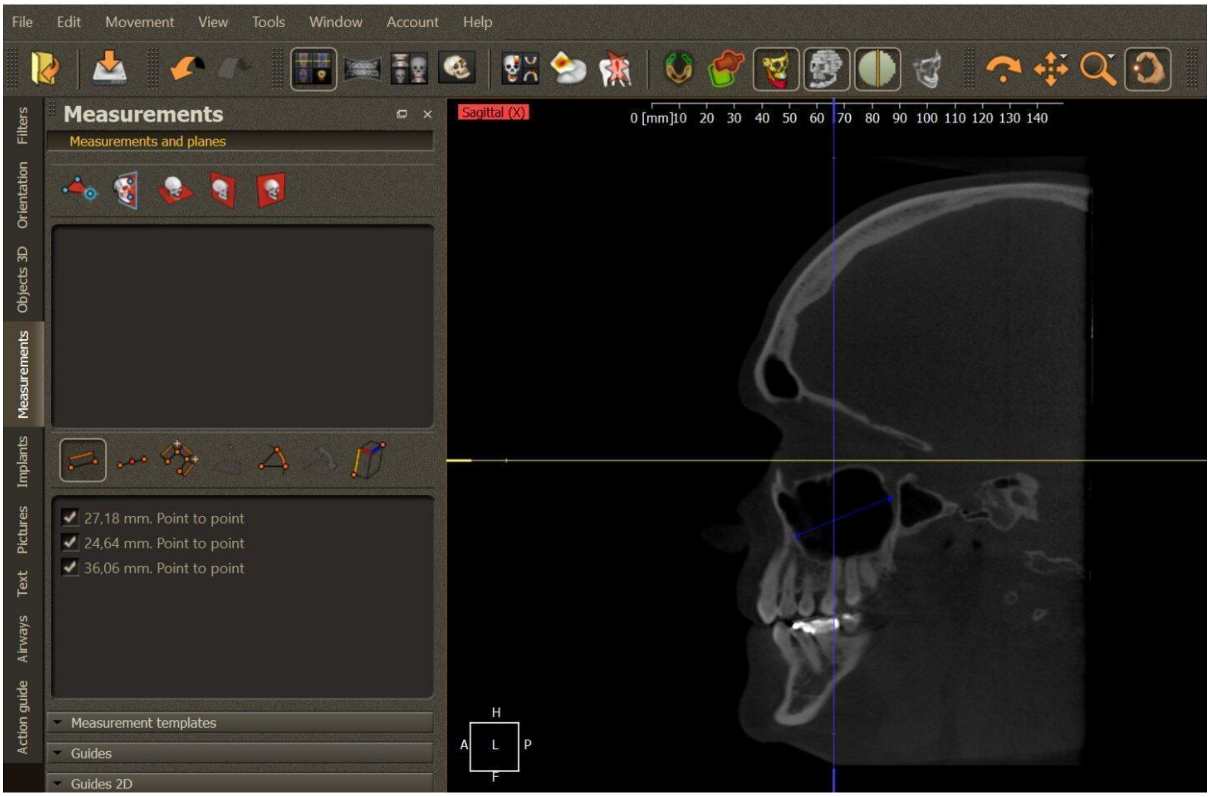

Fig. 2. Linear measurement (depth) of a maxillary sinus in the sagittal plane.
Source: Own elaboration.

Statistical analysis

For assessing reproducibility, two examiners performed the linear measurements of height, width, and depth, separately (n=30) at intervals of at least seven days. The inter- and intra-examiner reproducibility of measurements was evaluated with TEM (technical error of measurement), rTEM (relative technical error of measurement), and R (coefficient of reliability). The TEM is the most common way of expressing the margin of error in anthropometry, indicating accuracy, and representing the dimension of measurement quality control [25]. The TEM and rTEM were used to verify measurement reliability [26-29].

The data were subjected to descriptive and exploratory analyses, followed by paired t-tests to compare the left and right sides. The means of the left and right sides of each participant were calculated and new descriptive and exploratory analyses were performed on these means. Student's t-test was used for comparisons in cases of two categories (sex, skin color, and BMI). Analysis of variance (ANOVA) was used for the three age groups. However, for all variables, generalized linear models were used when the data did not meet the assumptions of the test.

Measurement means were also estimated with 95% confidence intervals corresponding to sex and age group. All analyses were performed with the R software at a 5% significance level [30].

Results

Table 1 shows that 58.4% of the sample were women and 41.6% were men. Also, 49.6% were 18 years or older, 20.6% were 6 to 11 years old, and 29.0% were 12 to 17 years old. As for skin color, 76.5% of the sample was white.

Table 1
Profile of the sample studied (n=238).

Variable	Category	Frequency (%)
Sex	Female	139 (58,4%)
	Male	99 (41,6%)
Age group (years)	From 6 to 11	49 (20,6%)
	From 12 to 17	69 (29,0%)
	18 or older	118 (49,6%)
	No information	2 (0,8%)
Skin color	White	182 (76,5%)
	Black	47 (19,5%)
	No information	9 (3,8%)
BMI	Normal	58 (24,4%)
	Above normal	61 (25,6%)
	No information	119 (50,0%)

BMI = Body mass index

Table 2 presents the results of the analysis of measurement reproducibility (intra- and inter-examiner).

Table 2
Results of the analyses of inter- and intra-examiner errors in measurements (n=30).

Variable	Side	Intra-examiner			Inter-examiner		
		TEM	rTEM	R	TEM	rTEM	R
Maxillary sinus height	Left	0,228	0,884	0,998	0,372	1,438	0,995
	Right	0,228	0,833	0,998	0,327	1,192	0,996
Maxillary sinus width	Left	0,214	0,967	0,997	0,285	1,293	0,994
	Right	0,213	1,036	0,996	0,306	1,489	0,993
Maxillary sinus depth	Left	0,205	0,570	0,997	0,298	0,830	0,993
	Right	0,230	0,648	0,996	0,377	1,056	0,988

TEM: technical error of measurement; rTEM: relative technical error of measurement; R: coefficient of reliability.

The MS height measurements were significantly higher on the right side ($p<0.05$). The mean variation between the two sides was 1.57 mm, varying between -14.10 mm (greater on the left side) and 15.50 mm (greater on the right side). For MS width, the measurements were significantly higher on the left side ($p<0.05$). The mean variation between the sides was 1.82 mm, varying from -11.30 mm (greater on the left side) to 11.20 mm (greater on the right side). For sinus depth, the left side showed higher values but without significant differences ($p>0.05$) (Table 3 and Figure 3).

Table 3
Results of the analyses of sides comparisons (mm).

Variable	Side				Difference between the sides		[1]p-value
	Left		Right				
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus height	24,55 (4,92) B	24,00 (14,40; 40,40)	26,13 (5,61) A	26,05 (11,50; 42,80)	1,57 (3,89)	1,25 (-14,10; 15,50)	<0,0001
Maxillary sinus width	23,47 (4,04) A	23,50 (14,40; 36,70)	21,65 (3,99) B	21,35 (11,60; 33,60)	-1,82 (3,37)	-1,65 (-11,30; 11,20)	<0,0001
Maxillary sinus depth	34,01 (3,91) A	34,00 (13,20; 43,40)	33,80 (3,45) A	33,75 (22,80; 41,70)	-0,21 (2,76)	-0,20 (-8,00; 15,40)	0,2416

[1]Paired t-test. Distinct horizontal letters indicate significant differences between sides (p≤0.05).

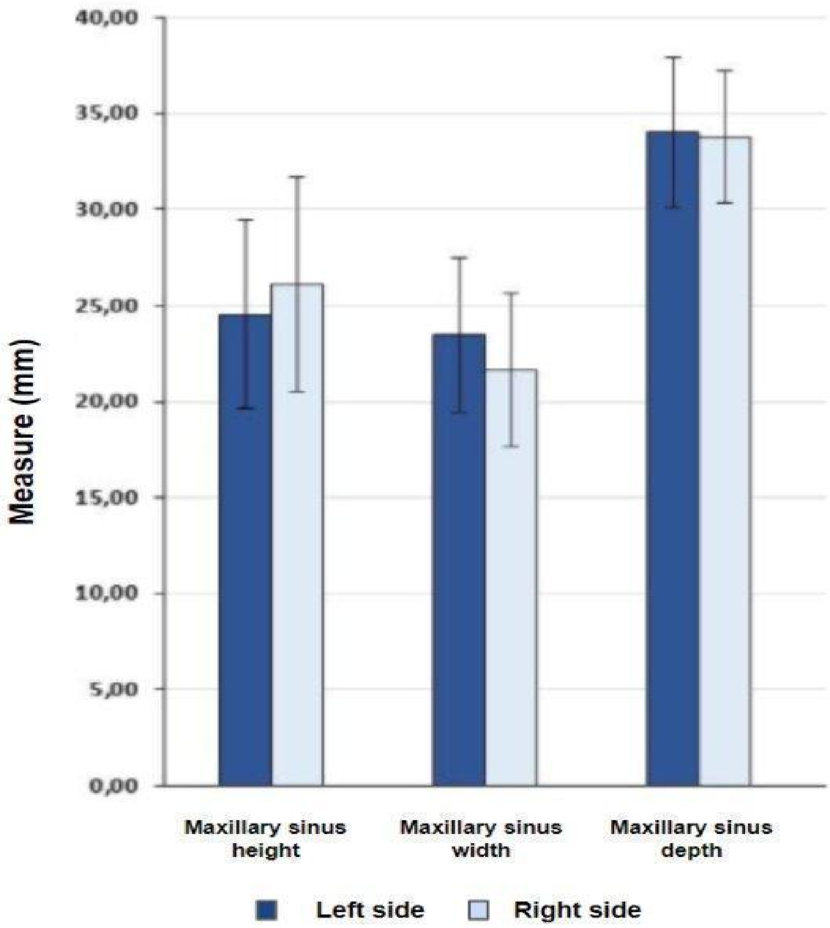

Fig. 3. Mean and standard deviation of measurements of the height, width and depth of the maxillary sinus (mm), regarding side.

The comparison of sexes (Table 4 and Figure 4) showed that men had higher values than women in all measures, but MS width was significantly greater in men ($p<0.05$). There were no significant differences between the sexes regarding height and depth ($p>0.05$).

Table 4
Results of the analyses of sexes comparisons (mm).

Variable	Sex				p-value
	Female		Male		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus height	25,05 (4,42) A	24,60 (15,95; 36,75)	25,73 (5,51) A	25,23 (13,30; 41,60)	[1]0,2975
Maxillary sinus width	22,14 (3,43) B	22,00 (14,85; 30,90)	23,16 (3,87) A	22,70 (14,90; 31,85)	[1]0,0331
Maxillary sinus depth	33,78 (3,21) A	33,60 (20,90; 41,80)	34,09 (3,70) A	33,95 (24,8;0 41,80)	[2]0,5032

[1]Student's t-test t; [2]Generalized linear model. Distinct horizontal letters indicate significant differences between sexes ($p \leq 0.05$).

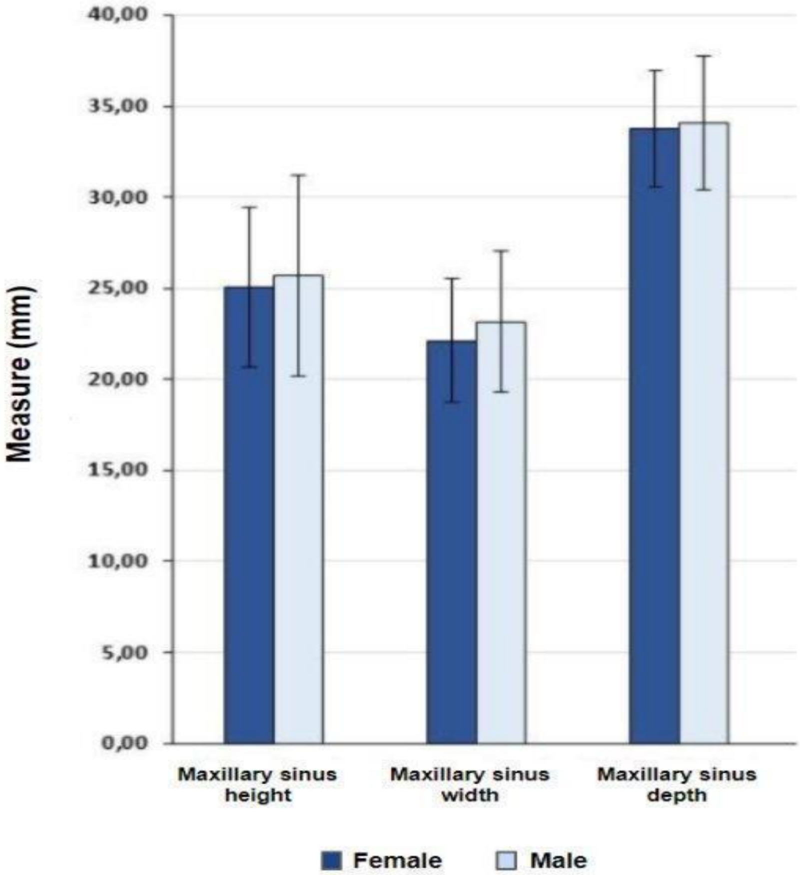

Fig. 4. Mean and standard deviation of measurements of the height, width and depth of the maxillary sinus (mm), regarding sex.

The age group of 12 to 17 years presented greater MS height and depth than 6 to 11 years old ($p<0.05$). The MS height was significantly greater in 18 years or older than from 12 to 17 years old ($p<0.05$). The MS height and depth were also significantly higher in 18 years or older than from 6 to 11 years old ($p<0.05$). The MS width was significantly smaller in the age group of 18 years or older ($p<0.05$) (Table 5 and Figure 5).

Table 5
Results of the analysis of comparisons between age groups (mm).

Variable	Age group (years)						[1]p-value
	6 to 11		12 to 17		18 and older		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus height	20,83 (3,57) C	20,85 (13,30; 29,95)	24,72 (4,10) B	24,25 (15,75; 36,40)	27,63 (4,34) A	27,85 (17,55; 41,60)	<0,0001
Maxillary sinus width	23,31 (3,36) A	23,10 (17,05; 30,40)	23,19 (3,65) A	23,15 (15,00; 31,85)	21,95 (3,66) B	21,70 (14,85; 30,90)	0,0243
Maxillary sinus depth	32,00 (2,94) B	32,65 (20,90; 37,00)	33,88 (3,13) A	33,65 (27,70; 41,80)	34,79 (3,40) A	34,60 (24,55; 41,80)	<0,0001

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups ($p \leq 0.05$).

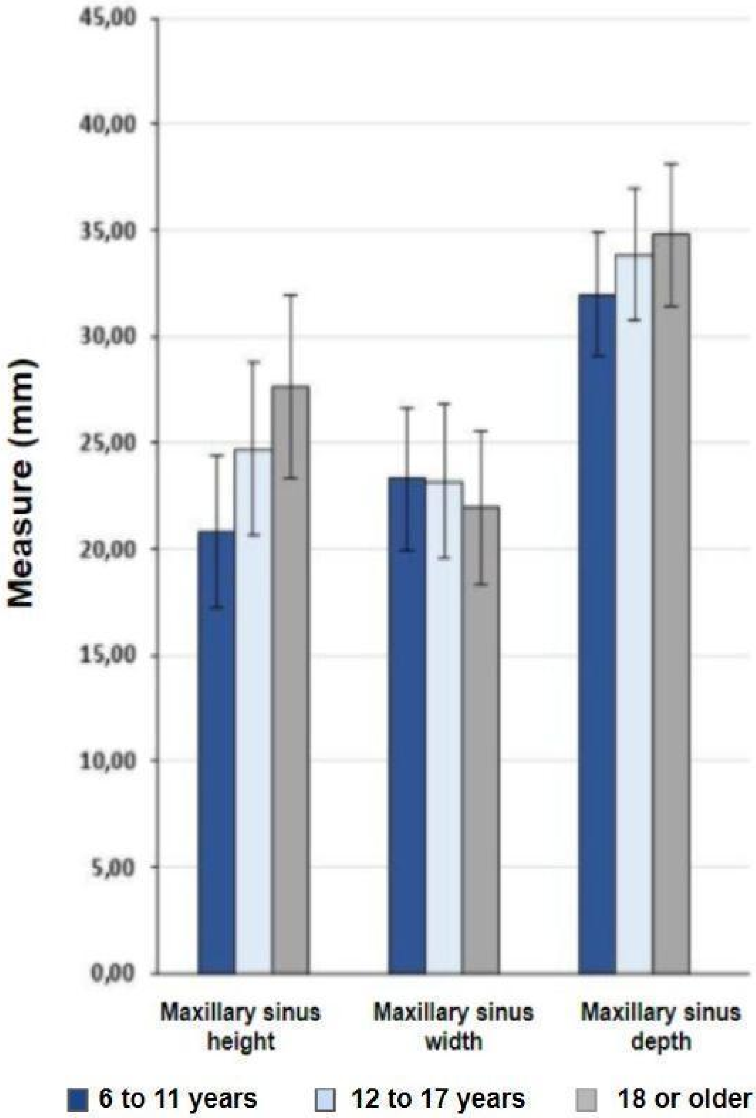

Fig. 5. Mean and standard deviation of measurements of the height, width and depth of the maxillary sinus (mm), regarding age group.

White individuals showed higher values than black individuals, and those with normal BMI showed higher values than those with BMI above normal, but there was no significant difference (p>0.05) in the measurements for skin color and BMI (Tables 6 and 7).

Table 6
Results of the analyses of skin color comparisons (mm).

Variable	Skin color				p-value
	White		Black		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus height	25,55 (4,76) A	24,98 (13,30; 41,60)	24,31 (4,99) A	23,90 (14,85; 37,10)	[2]0,1134
Maxillary sinus width	22,83 (3,55) A	22,63 (14,85; 30,90)	21,73 (4,03) A	21,30 (14,90; 31,85)	[1]0,0670
Maxillary sinus depth	33,88 (3,26) A	33,80 (20,90; 41,80)	33,77 (3,74) A	33,40 (27,95; 41,80)	[2]0,8384

[1]Student's t-test t; [2]Generalized linear model. Distinct horizontal letters indicate significant differences between skin color ($p \leq 0.05$).

Table 7
Results of analyses of BMI categories comparisons (mm).

Variable	BMI				[1]p-value
	Normal		Above normal		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Maxillary sinus height	25,18 (5,04) A	24,70 (13,30; 37,70)	24,70 (4,53) A	24,40 (16,20; 36,40)	0,5881
Maxillary sinus width	22,71 (3,75) A	22,50 (14,85; 31,85)	22,21 (3,80) A	21,95 (15,90; 30,40)	0,4693
Maxillary sinus depth	34,18 (3,12) A	33,88 (24,55; 41,50)	33,32 (3,09) A	33,20 (26,00; 40,70)	0,1324

[1]Generalized linear model. BMI = Body mass index.

Table 8 shows the estimates of each measure with the respective 95% confidence interval regarding sex and age group.

Table 8

Estimation of maxillary sinus linear measurements (mm) for sexes and age groups.

Variable	Sex	Age group (years)					
		6 to 11		12 to 17		18 and older	
		Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%
Maxillary sinus height	Female	21,01 (3,46)	19,65 - 22,38	23,95 (3,57)	22,72 - 25,18	26,97 (3,96)	26,07 - 27,87
	Male	20,59 (3,78)	18,92 - 22,27	25,51 (4,49)	23,95 - 27,08	28,89 (4,80)	27,35 - 30,42
Maxillary sinus width	Female	23,11 (3,11)	21,88 - 24,33	22,48 (3,54)	21,26 - 23,69	21,65 (3,43)	20,87 - 22,43
	Male	23,57 (3,71)	21,93 - 25,21	23,92 (3,67)	22,64 - 25,2	22,53 (4,03)	21,24 - 23,83
Maxillary sinus depth	Female	32,14 (3,23)	30,87 - 33,42	33,57 (3,25)	32,45 - 34,69	34,45 (3,00)	33,77 - 35,13
	Male	31,82 (2,61)	30,66 - 32,98	34,19 (3,02)	33,13 - 35,25	35,43 (4,04)	34,14 - 36,72

CI: Confidence interval

Discussion

As a result of the increase in crime worldwide along with accidents of multiple causes, the rate of deaths and missing persons has increased substantially. The most frequent accidents are natural disasters and car and air accidents. However, determining the identity of individuals through identification methods is extremely important, regardless of the cause of death, as it plays a legal role with direct implications in civil and criminal proceedings, also dealing with humanitarian issues [31-33].

Several studies have evaluated paranasal sinuses to identify individuals [14,34-36] using extraoral radiographs [37-39] and CT scans [34-36,38].

This study performed two-dimensional MS measurements (height, width, and depth), verified a potential difference between the left and right sides and analyzed the influence of sex, age, skin color, and nutritional status.

The Technical Error Measurement (TEM) is used to calculate intra-examiner variability, which is the variation in repeated measurements by the same examiner in the same person or a group of people. It also calculates inter-examiner variability, which is the variation in measurements made by different examiners within the same group of individuals [25,40]. The intra- and inter-examiner TEM and rTEM results obtained in this study for linear measurements showed data reliability. Moreover, because R values were very close to one, such analyses indicated excellent precision and reproducibility of measurements. Using CBCT images and performing digital measurements is valuable for obtaining more accurate measures.

There was a significant difference between the left and right sides for the measurements of MS height and width ($p<0.05$), except for depth. This differed from the studies by Bangi et al. [41], Urooge & Patil [42], Faria Gomes et al. [43], Waluyo et al. [44], and Teixeira et al. [45], which did not find statistically significant differences between the sides.

Sex estimation is important for identification. Several studies with different populations obtained higher linear MS measurements for men than for women [43,45-51], which agrees with the present study. However, the study by Najem et al. [52] analyzed the same measurements in a sample of 82 Egyptian subjects and did not find differences between the sexes.

In this study, MS width was greater ($p<0.05$) in men, indicating the possibility of using this measure to analyze sexual dimorphism. Vidya et al. [53] showed that the left MS width was the discrimination parameter, which could be used to study sexual dimorphism. Ahmed et al. [54], Azhar et al. [55], and Urooge & Patil [42] also indicated that the width of the left MS was the best discriminant parameter to study sexual dimorphism, which is consistent with the present study. However, some studies have shown that, among the parameters evaluated, MS height was the best discriminant variable for sexual dimorphism [45,46,56,57]. Likewise, Faria Gomes et al. [43] stated that height is the most dimorphic measure with the best potential to estimate sex.

The mean MS height, width, and depth obtained in this study were, for the right side, respectively, 26.13 mm, 21.65 mm, and 33.80 mm, and for the left side, 24.55 mm, 23.47 mm, and 34.01 mm. In the study by Uthman et al. [46], the differences in MS width on the right and left sides were significant only for men, with a mean of 24.7 mm for the right side and 25.6 mm for the left side. The means for women were 22.7 mm for the right side and 23 mm for the left side. Regarding length, there was no statistically significant difference for both sexes regarding the sides, with means for women of 36.9 mm for the right side and 37 mm for the left side, and for men of 39.3 mm for the right side and 39.4 mm for the left side. For height, a statistically significant difference for the sides was observed only in men, with means of 43.3 mm for the right side and 45.1 mm for the left side. The means for women were 39.9 mm for the right side and 40 mm for the left side.

Kanthem et al. [49] studied a sample of Indian individuals and found mean values of MS height, length, and width for men on the right side of 4 mm, 3.76 mm, and 2.63 mm, respectively, and the means for women were 3.09 mm, 3.12 mm, and 2.23 mm. The mean values of MS height, depth, and width for men on the left side were 3.93 mm, 3.73 mm, and 2.53 mm, respectively, and the means for women were 3.07 mm, 3.12 mm, and 2.20 mm.

Rani et al. [50] also studied a sample of Indian individuals, and the mean values for MS height, width, and depth for men on the right side were 3.89 mm, 4.11 mm, and 4.32 mm, respectively, while the means for women were 3.21 mm, 3.79 mm, and 3.88 mm, respectively. There was a statistically significant difference between the mean dimensions of height, width, and depth of the right MS. The mean values of height, width, and depth of the left MS for men were 3.88 mm, 4.09 mm, and 4.27 mm, respectively, while the means for women were 3.18 mm, 3.74 mm, and 3.82 mm. There was a statistically significant difference among the mean dimensions of height, width, depth, and volume of the left MS.

Therefore, it is important to have specific data for different populations. The literature has reported differences between populations [58] and within the same population, such as the data obtained by Kanthem et al. [49] and Rani et al. [50].

Using samples of Brazilian individuals, Oliveira et al. [59] evaluated the measurement of the relative MS area (height and width) by analyzing computed tomography (CT) scans of 60 subjects. Farias Gomes et al. [43] developed and validated a formula for estimating sex from linear and volumetric MS measurements of 94 subjects, using CBCTs. Mendonça et al. [51], using multislice CT, evaluated the accuracy of linear MS measurements (height, width, and diameter) in estimating sex in 140 adults.

Regarding age groups, MS height was significantly higher in 18 years or older than from 12 to 17 years old ($p<0.05$). The MS height and depth were also significantly higher in 18 years or older than from 6 to 11 years old ($p<0.05$). There were significantly smaller measurements in the age group of 18 years or older than the other age groups for MS width ($p<0.05$).

The study by Teixeira et al. [45] divided the sample into two age groups (18–40 years and >40 years) and performed measurements of maximum height, width, and length, intersinus distance, and maximum total width. Regarding age, except for intersinus distance, all measurements were higher in the younger group (18–40 years), and this parameter was the best individual discriminator. According to Rani et al. [50], regarding the age group (from 21 to 73 years old), all variables (width, depth, and height) showed a significant difference and decreased with age. Najem et al. [52] divided individuals aged 20-65 years into two age groups (≤40 (n=60) and >40 years (n=22), also measuring MS height, width, and length bilaterally, and did not find significant differences between the ages. It is impossible to establish comparative parameters of our findings with the studies aforementioned because the age groups are different from those of the present study and the authors did not use samples from individuals under 18 years of age. Due to the scarcity of investigations on age prediction, the findings of the present study may be a starting point for further investigations in this field.

So far, the literature does not have studies on the influence of skin color and nutritional status on MS measurements, which did not allow establishing comparative parameters.

White individuals showed higher values than black individuals, and those with normal BMI showed higher values than those with BMI above normal. However, according to the analyses, these measures did not show significant differences ($p>0.05$), confirming the impossibility to demonstrate, with the available data, a relationship between the variables analyzed. However, further research is required.

The estimates of each measure with the respective 95% confidence interval according to sex and age group from this study can be used in Forensic Sciences, particularly Forensic Anthropology, and to identify Brazilian individuals, therefore, assisting Justice and society.

For the Brazilian population, this is one of the few studies of two-dimensional MS measurement that use CBCT with a considerably larger sample (n= 238) than other published studies. The values presented in Table 8, including the estimates made with a 95%confidence interval calculated from our findings according to sex and age group, can contribute to Forensic Sciences and assist real forensic cases.

Conclusion

The results of the present study showed that the measurements of MS height and width had significant differences between the right and left sides, and there was anatomic variability between the sexes for MS width. Men showed greater MS width than women, which may help analyze sexual dimorphism. However, height and depth measurements did not show significant differences between the sexes. There were significant differences between age groups. There was no significant difference in the measurements for skin color and nutritional status.

Ethical approval

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University (Unesp).

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Conflicts of interest

There are no conflicts of interest.

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3.5 Publicação 5[5*]

Three-dimensional CBCT analysis of sphenoid sinuses of a Brazilian population, related to sex, age, skin color, and nutritional status using the DDS-Pro™ software[1]

Abstract

Sphenoid sinuses (SS) are important for human identification because they are structures with individualizing characteristics. This study aimed to perform a three-dimensional analysis (volume and area) from cone-beam computed tomography (CBCT) images of SS of a Brazilian population using the beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland) and to assess a potential correlation to sex, age, skin color, and nutritional status. It also evaluated the differences between the right and left sides. Three-dimensional volume and area measurements were made with the software using CBCT images of 113 living Brazilian individuals of both sexes (67 women and 46 men). The TEM, rTEM, and R were used to assess the reproducibility of inter- and intra-examiner measurements. The measurement means were estimated with 95% confidence intervals according to sex and age group. There were no significant differences between the left and right sides for both volume and area, and between the sexes and black and white individuals. Volume and area were significantly higher in 18 years or older ($p<0.05$) and in individuals with normal body mass index -BMI ($p<0.05$). The obtained results do not allow indicating the use of SS volume and area measurements to estimate sexual dimorphism, and the same occurred for skin color. However, such measures can help to estimate age. Nevertheless, further studies are suggested with a larger sample, especially for the nutritional status variable.

Keywords: Human identification; Sphenoid sinus; Cone-Beam Computed Tomography; Three-Dimensional imaging, Forensic anthropology; Forensic dentistry.

[5*] Artigo descrito segundo as normas do periódico *International Journal of Legal Medicine*.

[1] O material e métodos deste estudo foram obtidos do trabalho de tese de doutorado da própria autora.

Introduction

The percentage of people killed and missing has increased substantially due to rising crime rates worldwide and accidents from multiple causes. The most common accidents are natural disasters and car and air accidents. However, identifying individuals, regardless of the cause of death, is extremely important because it deals with humanitarian issues and has a legal function in civil and criminal proceedings [1-3].

The study of anthropometry is essential to clarify issues related to human identification due to its importance in performing linear, angular, area, and volume measurements in different body components [4]. Therefore, the anthropometric analysis of the skeleton provides primary characteristics of individuals such as sex, age at death, ancestry, and height [5]. Craniometry is essential in the Forensic field, especially in Forensic Dentistry, because the identity of a body is often defined only with the help of the skull through craniometric characteristics [6].

Craniofacial structures are more resistant to accidental impacts and, therefore, have advantages over others [7]. Among these structures are paranasal sinuses, which provide valuable information to Forensic Sciences for identifying individuals [8,9]. Similar to the frontal sinus (SF), the morphology of sphenoid sinuses (SS) presents high heterogeneity, and it is considered one of the most variable cavities in the human body [10], thus very useful for identification [11].

The radiological evaluation of paranasal sinuses and related structures aims to accurately describe the anatomical region, show any bone changes or variations in the sinus mucosa and fluid levels, and establish the presence and extent of pathologies [12,13]. Imaging methods used for this purpose include radiographs (two-dimensional scans) such as Waters and panoramic, magnetic resonance imaging (MRI), computed tomography (CT), and cone-beam computed tomography (CBCT) [9,12,14].

This study aimed to perform a three-dimensional analysis (volume and area) from cone-beam computed tomography (CBCT) images of SS of a Brazilian population, using the beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland), and to assess a potential correlation to sex, age, skin color, and nutritional status (with the body mass index – BMI). It also evaluated the differences between the right and left sides. There are few published data concerning 3D sphenoid sinuses measurements using CBCT, specially concerning Brazilian population. This is the first study that evaluates the influence of skin color and nutritional status on sphenoid sinuses volume and area.

Materials and Methods

The sample of this study consisted of head and neck CBCT images of 113 living Brazilian subjects of both sexes (67 women and 46 men), aged between 6 and 68 years. The variables of age, skin color, and nutritional status (with BMI analysis) were also considered, but some variables were not considered entirely because not all of them presented complete data. The age groups were divided into 06 to 11 years (n=19), 12 to 17 years (n=31), and 18 years or older (62 adults). Regarding skin color, there were 83 white individuals and 26 black individuals. The following formula was used for BMI calculation: BMI = weight/height^2. Regarding nutritional status, there were 23 individuals with a normal BMI (between 18.5 and 24.9) and 35 with BMI above normal (above 25) [14] (Table 1). Images of sphenoid sinuses with pathologies, obliterations, and/or trauma were excluded.

This project was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University - Unesp (CAAE - nº 47706121.4.0000.5416). The images analyzed came from an image bank owned by one of the researchers, and the identity of the individuals remained confidential.

Two examiners measured SS on both sides (right and left), with at least seven days between the first and second measurements. When one of the sinuses met the exclusion criteria, only the other one was measured.

The acquisitions were obtained by an i-CAT cone-beam tomography scanner. The volumetric measurements were obtained with a beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland), developed to allow semi-automated three-dimensional measurements. The images selected were made available and used in DICOM (Digital Imaging and Communications in Medicine) language.

In the beta version of the DDS-Pro™ 2.14.2_2022 software (DPP Systems, Czestochowa, Poland), the “Airways” option and the “Point tools” were used for determining SS in the sagittal, axial, and coronal planes with the following parameters (Figure 1-2):

- Blocker radius: 10.00
- Difference from: -300
- Difference to: 300
- Maximal opening diameter: 2.00

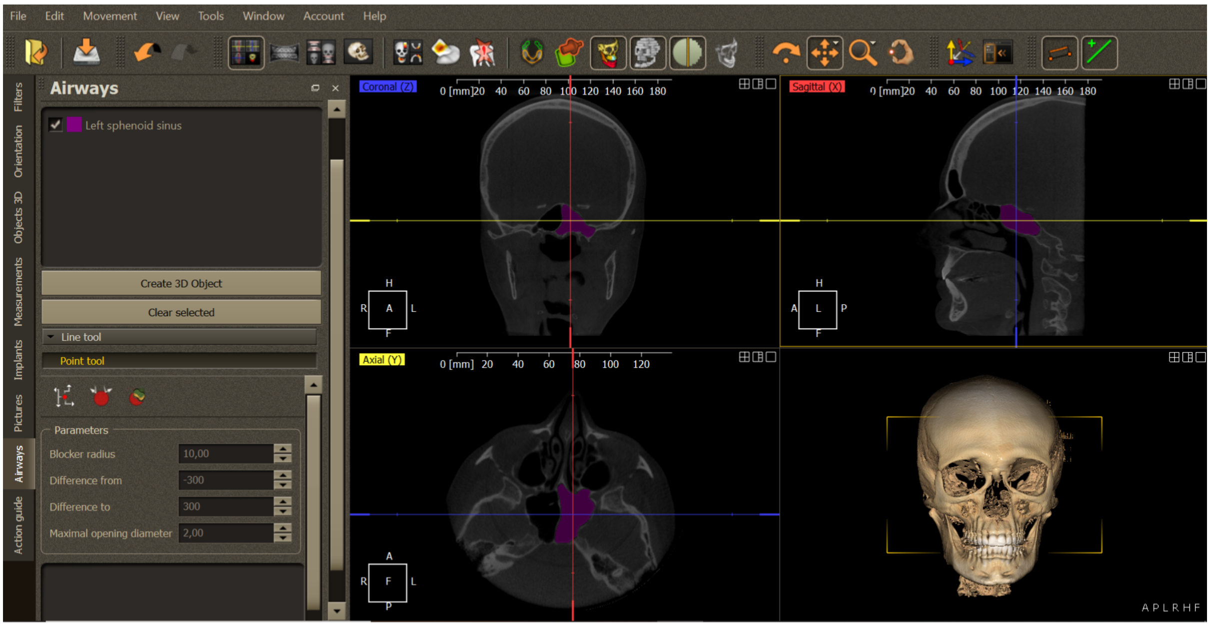

Fig. 1 Delimitation of a sphenoid sinus in the axial, sagittal and coronal planes, using DDS-Pro™ software. The employed parameters of the tool “point tools” (Blocker radius: 10.00; Difference from: -300; Difference to: 300; Maximal opening diameter: 2.00) are visible on the lower left side of the image. Source: Own elaboration.

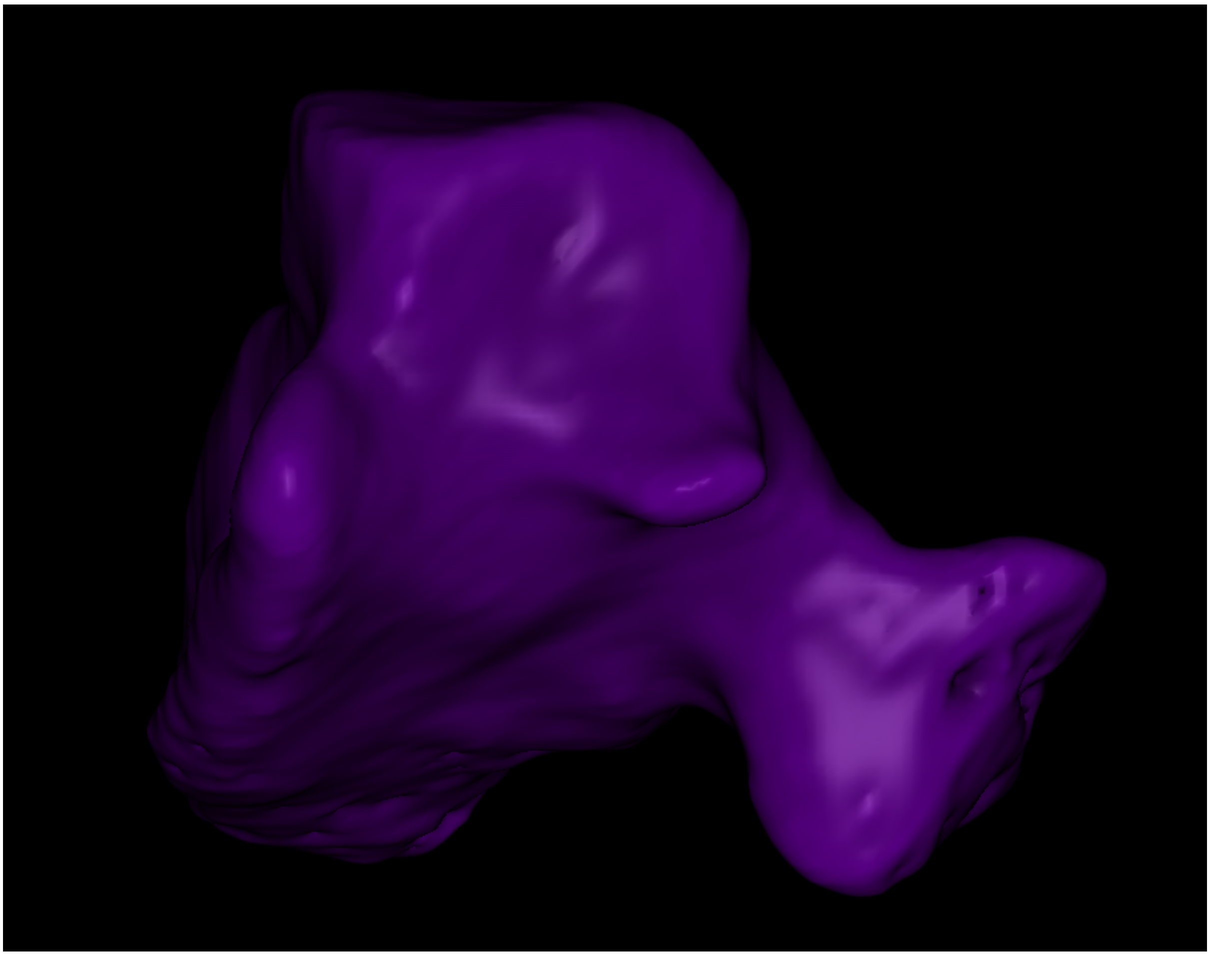

Fig. 2 Three-dimensional volumetric image of a left sphenoid sinus, obtained from a cone-beam computer tomography, using DDS-Pro™ software. Source: Own elaboration

Statistical analysis

The inter- and intra-examiner reproducibility of measurements was evaluated by TEM (technical error of measurement), rTEM (relative technical error of measurement), and R (coefficient of reliability). Descriptive and exploratory data analyses were performed, and generalized linear models were used to analyze the left and right sides regarding SS area and volume, considering the model and dependence between the sides of the same participant.

The means of the left and right sides of each subject were calculated and a new descriptive and exploratory analysis was performed for these means. Generalized linear models were then used to analyze sex, age range, skin color, and BMI relative to area and volume. The measurement means were also estimated with the respective 95% confidence intervals regarding sex and age group. All analyses were performed with the R software at a 5% significance level [15].

Results

Table 1 shows that 59.3% of the sample were women and 40.7% were men. Also, 54.9% ere 18 years or older, 16.1% were 6 to 11 years old, and 27.4% were 12 to 17 years old. The skin color of 73.4% of the sample was white.

Table 1 Profile of the sample studied (n=113).

Variable	Category	Frequency (%)
Sex	Female	67 (59,3%)
	Male	46 (40,7%)
Age group (years)	From 6 to 11	19 (16,1%)
	From 12 to 17	31 (27,4%)
	18 or older	62 (54,9%)
	No information	1 (0,9%)
Skin color	White	83 (73,4%)
	Black	26 (23,0%)
	No information	4 (3,5%)
BMI	Normal	23 (20,4%)
	Above normal	35 (31,0%)
	No information	55 (48,7%)

BMI – Body mass index.

Table 2 presents the results of the analysis of measurement reproducibility (intra- and inter-examiner). The intra-examiner technical error of measurement (TEM) was 83.2 mm^2 for SS area and 305.0 mm^3 for volume. The intra-examiner relative technical error of measurement (rTEM) was 4.8% and 7.2% for area and volume, respectively. The values of coefficient of reliability (R) were very close to one, indicating excellent accuracy in the measurements. The inter-evaluator TEM was 125.1 mm^2 and 318.9 mm^3 for area and volume, respectively. The inter-examiner rTEM was 7.1% and 7.5% for area and volume, respectively. The inter-examiner coefficient of reliability (R) values was very close to one, also indicating excellent reproducibility in the measurements.

Table 2 Results of the analyses of inter- and intra-examiner errors in measurements (n=30).

Variable	Intra-examiner			Inter-examiner		
	TEM	rTEM	R	TEM	rTEM	R
Sphenoid sinus area	83,242	4,796	0,991	125,082	7,141	0,979
Sphenoid sinus volume	305,007	7,232	0,987	318,929	7,511	0,986

TEM: technical error of measurement; rTEM: relative technical error of measurement; R: coefficient of reliability.

There was no significant difference between the sides of the participants regarding SS area and volume (p>0.05) (Table 3). There was also no significant difference between the sexes (p>0.05) (Table 4). However, both SS area and volume SS were significantly higher in 18 years or older than in the other two age groups (p<0.05) (Table 5 and Figures 3 and 4).

Table 3 Results of the analyses of sides comparisons.

Variable	Side				Difference between the sides		¹p-value
	Left		Right				
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus area (mm^2)	1.534,65 (978,91)	1.382,65 (279,29; 5.406,65)	1.508,8 (644,69)	1.477,51 (337,47; 2.925,8)	25,85 (1.034,85)	36,22 (-4.291,29; 2.132,06)	0,7940
Sphenoid sinus volume (mm^3)	3.582,3 (2.748,52)	3.080,63 (376,35; 12.554,1)	3.521,17 (1.992,19)	3.034,24 (452,63; 8.879,06)	61,13 (3.078,94)	92,21 (-8.509,13; 6.294,94)	0,8523

¹Generalized linear model.

Table 4 Results of the analyses of sexes comparisons.

Variable	Sex				[1]p-value
	Female		Male		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus area (mm^2)	1.658,52 (766,14)	1.542,99 (557,12; 4.609,96)	1.681,56 (765,91)	1.635,86 (390,14; 3.647,67)	0,8736
Sphenoid sinus volume (mm^3)	4.014,99 (2.411,17)	3.251,86 (906,54; 1.1457,9)	4.034,97 (2.072,9)	4.078,23 (522,16; 8.763,91)	0,9634

[1]Generalized linear model.

Table 5 Results of the analyses of age group comparisons.

Variable	Age group (years)						[1]p-value
	6 to 11		12 to 17		18 and older		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus area (mm^2)	1.317,04 (743,44) B	1.132,44 (475,6; 3.058,7)	1.491,19 (615,38) B	1.565,82 (390,14; 2.730,77)	1.877,84 (779,27) A	1791,61 (557,12; 4.609,96)	0,0009
Sphenoid sinus volume (mm^3)	2.948,01 (2.122,1) B	2.523,39 (829,79; 8.473,05)	3.369,89 (1.723,15) B	3.226,09 (522,16; 6.831,85)	4.712,54 (2.353,97) A	4.160,68 (958,65; 1.1457,9)	0,0029

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups ($p \leq 0.05$).

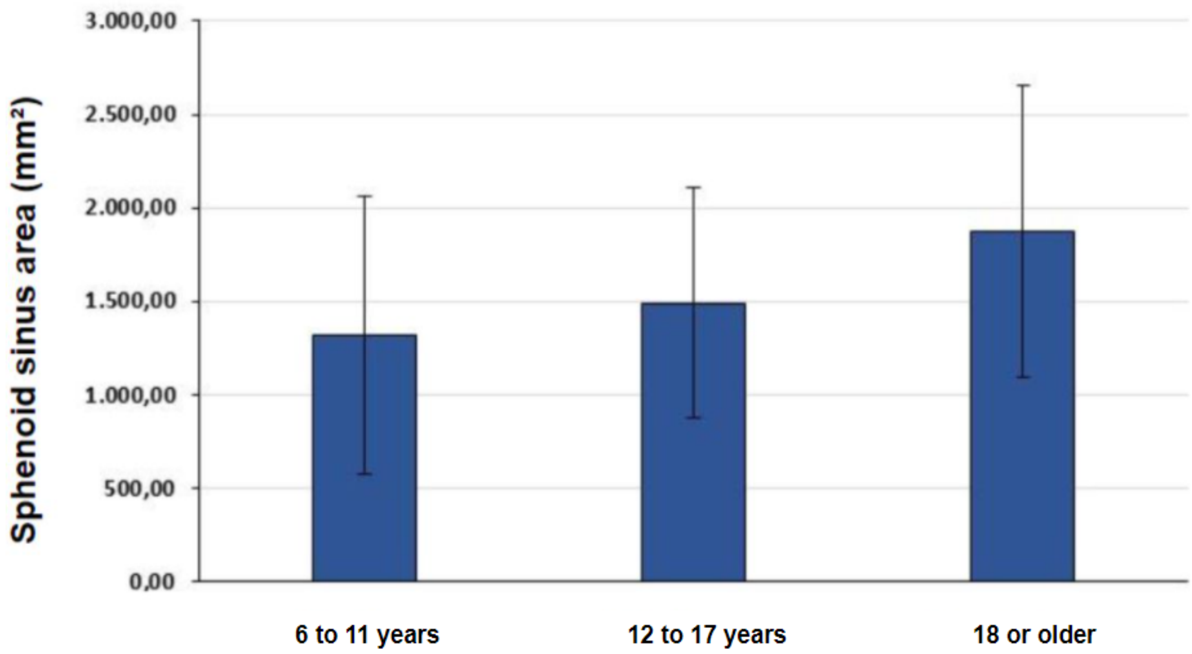

Fig. 3 Mean (standard deviation) of the sphenoid sinus area (mm^2) regarding age groups (6-11 y.o.; 12-17 y.o. and 18 y.o. or older). The values are defined in Table 5.

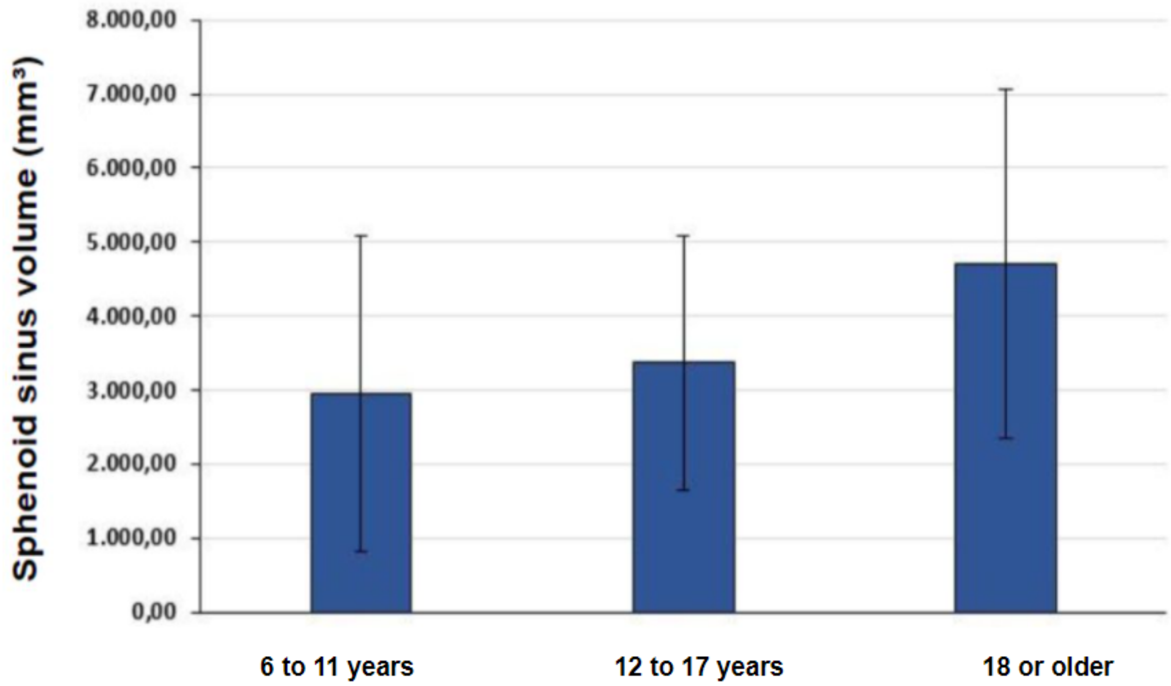

Fig. 4 Mean (standard deviation) of sphenoid sinus volume (mm^3) regarding age group (6-11 y.o.; 12-17 y.o. and 18 y.o. or older). The values are defined in Table 5.

Table 6 Results of the analyses of skin color comparisons.

Variable	Skin color				[1]p-value
	White		Black		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus area (mm^2)	1.717,99 (738,23)	1.568,68 (390,14; 3.647,67)	1.461,37 (610,68)	1.535,15 (475,6; 2.521,16)	0,1053
Sphenoid sinus volume (mm^3)	4.131,8 (2.258,75)	3.564,59 (522,16; 9.987,68)	3.562,32 (1.891,09)	3.705,38 (829,79; 7.586,26)	0,2422

[1]Generalized linear model.

Table 7 Results of analyses of BMI categories comparisons.

Variable	BMI				[1]p-value
	Normal		Above normal		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus area (mm^2)	1.932,18 (719,89) A	1.854,62 (617,77; 3.261,01)	1.511,98 (670,36) B	1.295,49 (390,14; 3.058,00)	0,0293
Sphenoid sinus volume (mm^3)	4.892,24 (2.191,10) A	5.149,30 (906,54; 9.987,68)	3.590,66 (2.003,93) B	3,300,07 (522,16; 8,473,05)	0,0290

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups (p≤0.05). BMI = Body Mass Index.

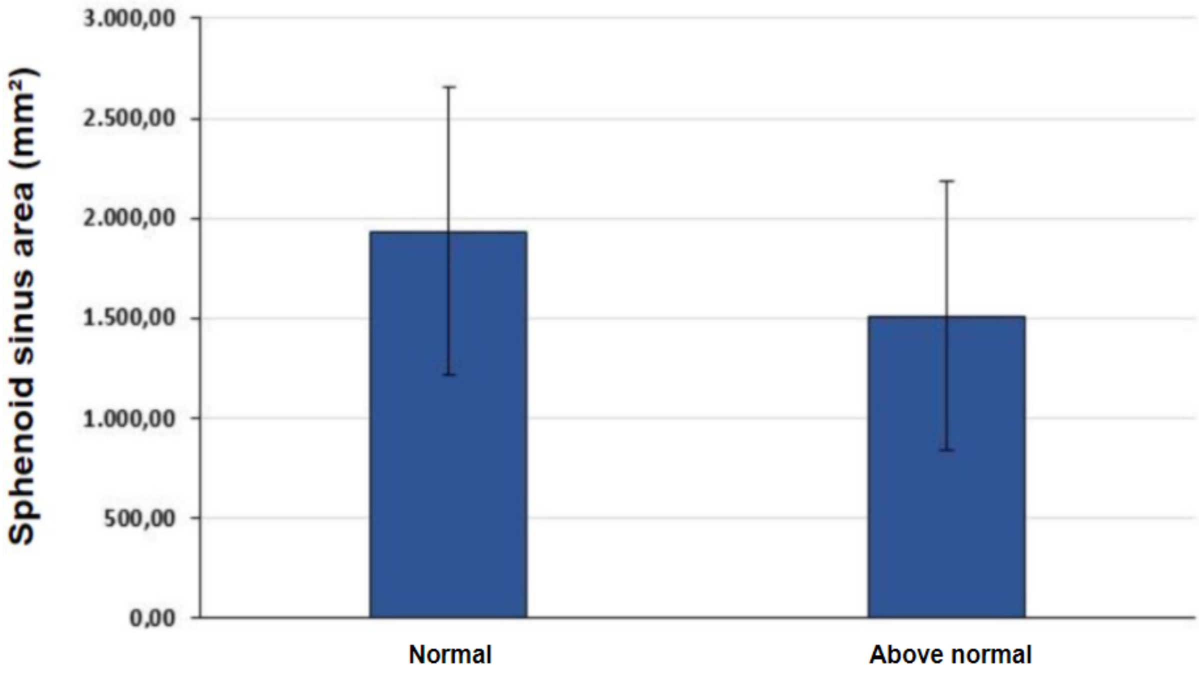

Fig. 5 Mean (standard deviation) of the sphenoid sinus area (mm^2) regarding BMI categories (normal and above normal). The values are defined in Table 7.

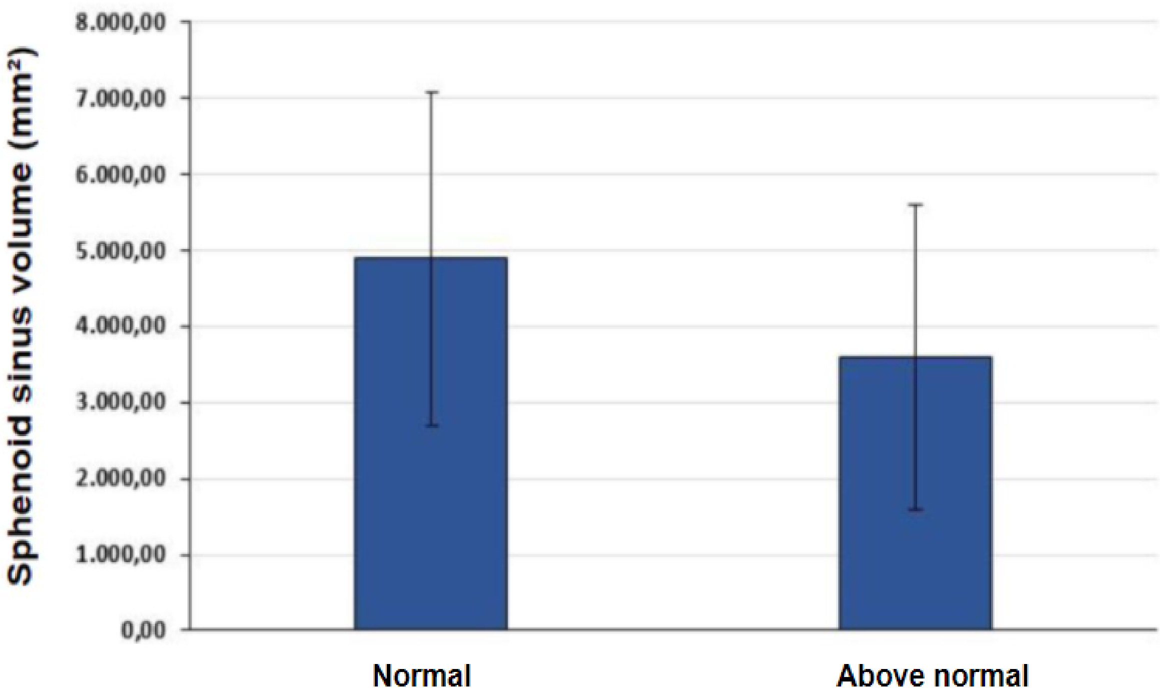

Fig. 6 Mean (standard deviation) of sphenoid sinus volume (mm^3) regarding BMI categories (normal and above normal). The values are defined in Table 7.

Table 8 shows the estimates of SS area and volume regarding sex and age group, with the respective 95% confidence intervals.

Table 8 Estimation of maxillary sinus area and volume measurements for males and females according to age groups.

Variable	Sex	Age group (years)					
		6 to 11		12 to 17		18 and older	
		Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%
Sphenoid sinus area (mm^2)	Female	1.281,75 (694,31)	785,07 – 1.778,43	1.342,15 (610,71)	989,53 – 1.694,76	1.849,15 (774,12)	1.610,91 – 2.087,39
	Male	1.356,25 (835,45)	714,06 – 1.998,44	1.613,93 (609,55)	1.300,53 – 1.927,34	1.942,76 (808,24)	1.553,2 – 2.332,32
Sphenoid sinus volume (mm^3)	Female	2.818,34 (2.119,54)	1.302,11 – 4.334,57	2.753,03 (1.508,65)	1.881,96 – 3.624,1	4.704,15 (2.471,97)	3.943,39 – 5.464,91
	Male	3.092,09 (2.243,67)	1.367,45 – 4.816,73	3.877,9 (1.763,77)	2.971,05 – 4.784,74	4.731,52 (2.125,96)	3.706,84 – 5.756,2

CI: Confidence interval

Discussion

Paranasal sinuses are located in the bones surrounding the nasal cavity and are named according to their anatomical relationships as maxillary (MS), ethmoid (ES), frontal (FS), and sphenoid (SS) sinuses. The bony walls that define the sinuses are very thin and can be lost during pathological processes such as the nasal cavity, oral cavity, orbit, and anterior cranial fossa [16-18].

Paranasal sinuses are considered pneumatic cavities because they are made up of air and covered by a mucoperiosteal membrane and ciliated cylindrical pseudostratified epithelium, in which they establish direct or indirect connections with the respiratory system. They ensure harmonious facial growth, making the skull lighter and protecting infraorbital and intracranial structures, partially compensating impacts [19].

The radiological evaluation of sinuses and related structures is designed to accurately describe the anatomical area, show any skeletal, sinus mucosal, and fluid level changes, and determine the presence and extent of pathological processes [12,13].

Considering the specificity of their contours, paranasal sinuses provide relevant information for determining the identity of individuals, allowing a detailed and explicit analysis, thus reducing the risk of errors during forensic investigations [8,9,20,21]. This study performed three-dimensional SS measurements (volume and area) and verified potential differences between the left and right sides and the influence of sex, age, skin color, and nutritional status using the BMI.

The Technical Error Measurement (TEM) reveals the margin of error in anthropometry and it is used as an accuracy parameter, as well as to portray the dimension of quality control of the measurements [22,23]. Therefore, the TEM and rTEM results obtained in this study, for intra- and inter-examiner measures, validate data reliability. The R values of both volume and area also indicated excellent precision and reproducibility of measurements, showing reliability, as they were very close to one.

There were no significant differences between the left and right sides for area and volume. Similarly, Emirzeoglu et al. [24] evaluated the SS volume of normal men and women in computed tomography (CT) images and did not find statistical differences between the sides in both sexes. It is worth noting that the authors did not measure the volume with 3D reconstructions of tomographic images but with two-dimensional measurements in the coronal plane, from which volume was estimated, differing from the methodology used in this study. Nejaim et al. [25] performed a volumetric analysis of SS with CBCT images and did not find significant differences between the volumes of the right and left sides. However, Oliveira et al. [26] analyzed and evaluated the variation of SS anatomy and volume with helical CT and found differences in sinus volumes on the right and left sides.

The present study did not show statistically significant differences between the sexes, which is similar to the studies by Cappella et al. [11], Nejaim et al. [25] and Oliveira et al. [26] which found that sex had no significant influence on SS volume. However, other studies with different populations obtained statistically different values between the sexes, which differs from this study [24,27-33], with higher values for men.

Oliveira et al. [27] evaluated the accuracy of SS volume and area measurements and the possibility of sexual dimorphism. The authors noted that men had a significantly higher mean than women and higher volume and area variations.

Regarding age, the sample in this study was classified into three age groups (06 - 11 years, 12 - 17 years, and 18 years or older). The age group of 18 years or older showed significantly higher values of SS area and volume than the other age groups, which indicates that volumetric measurements of the sinus can help estimate age. Emirzeoglu et al. [24] estimated SS volume with CT images and evaluated the effect of aging on the size of sinuses. The sample consisted of 77 individuals aged between 18 and 72 years.

According to the authors, there was a negative correlation between total sinus volume and age ($r=-0.238$; $P<0.05$), meaning that the sinus size tends to decrease with age. It is impossible to establish comparative parameters with the present study because the authors did not analyze images of subjects younger than 18 years of age.

The study by Jat et al. [34] used CT images to assess age in 64 healthy Indian subjects aged between 10 and 22 years. The SS volume was measured and the influence of age, sex, place of residence, and diet was analyzed. The authors divided the individuals into different age groups in intervals of 1, 2, 3, and 4 years. When estimated at a 1-year interval, the volumetric measurement was significant only in some age groups, but at a 2-year interval, there was a significant difference in most age groups. In the 4-year interval, the volumetric measurement of SS was significant in all age groups. The mean volumes of the rural population were higher than those of the urban population, and the mean volume was higher in non-vegetarians than in vegetarians.

Oliveira et al. [26] analyzed SS volume using helical CT images of 47 Brazilian subjects aged between 18 and 86 years and found that sinus volume was not affected by age. Cohen et al. [29] analyzed SS volume and assessed the impact of age and sex. The individuals were divided into two age groups: 65 years or younger and 65 years or older. Younger individuals showed significantly higher volumes than older individuals. Koç [31] analyzed the role of SS volumes to determine sex and age with CBCT images of 81 individuals. The author did not find a significant correlation between age and sinus volume ($p>0.05$).

The results obtained in this study may assist age estimation, considering the different age groups.

Regarding BMI and skin color, so far, there are no publications in the literature relating these variables to the 3D measurements of SS, which made it impossible to establish comparison parameters.

There was no significant difference between black and white individuals regarding the SS area and volume ($p>0.05$), showing the impossibility to validate, with the available data, a relationship between the parameters measured. However, regarding nutritional status, this study showed that both SS area and volume were significantly higher in participants with normal BMI than in individuals with a BMI above normal ($p<0.05$). Nevertheless, the sample of subjects with BMI information (n = 58) suggests further studies with more participants.

The values of SS area and volume presented in Table 8, calculated with a confidence interval of 95%, can contribute to Forensic Sciences in cases requiring age estimation.

Conclusion

There were no significant statistical differences between men and women, which does not allow indicating the application of measurements of SS volume and area to verify sexual dimorphism, and the same occurred for skin color. However, such measures can help estimate the age and nutritional status of individuals because there were significant differences in these groups. Based on our results, measurement estimates of sphenoid sinus volume and area according to sex and age group, performed with a 95% confidence interval, can be used in expert investigations. Nevertheless, further studies are suggested with a higher sample number, especially for the nutritional status variable.

Statements and Declarations

Compliance with Ethical Standards

Ethical approval

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University (Unesp).

Conflict of interest

The authors declare that they have no conflict of interest.

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3.6 Publicação 6[6*]

Analysis of linear measurements of sphenoid sinuses in CBCT images of Brazilian subjects: a contribution to Forensic Sciences[1]

Abstract

Objectives: To measure, in cone-beam computed tomography (CBCT) images, the height, width, and depth of sphenoid sinuses (SS) on the right and left sides of Brazilian individuals and verify potential significant differences between men and women of different age groups, skin color, and nutritional status.

Methods: The DDS-Pro™ 2.12.0_2021 software (DPP Systems, Czestochowa, Poland) measured SS height, width, and depth on both sides in CBCT images of a sample of 238 subjects. The inter- and intra-examiner reproducibility of measurements was evaluated with TEM, rTEM, and R. Statistical analyses were performed with the R software at a 5% significance level. Measurement means were also estimated with the respective 95% confidence intervals regarding sex and age group.

Results: There were no significant differences between the left and right sides. All SS measurements were higher in men, and the variable of height showed a significant difference ($p<0.05$). Only SS height did not show significant differences between the ages, and width and depth were significantly greater for the age group of 18 years or older. There was no significant difference in the measures studied for skin color (black and white) and nutritional status.

Conclusions: The SS measurements did not show significant differences between the right and left sides. There is an anatomical variability between the sexes regarding SS height, which can aid Forensic Sciences to determine sexual dimorphism. There were also significant differences between age groups but no significant differences in the measurements related to skin color and body mass index (BMI).

Keywords: Cone-beam computed tomography; Radiology and forensic imaging; Sphenoid sinus; Forensic dentistry; Human identification.

[6*] Artigo em revisão e descrito segundo as normas do periódico *Journal of Forensic and Legal Medicine*.

[1] O material e métodos deste estudo foram obtidos do trabalho de tese de doutorado da própria autora.

1. Introduction

Examining skeletal remains is common practice in both large-scale disasters and individual cases. The bodies found and taken to the Legal Medical Institute without suspicions on their identities require identification, making anthropological methods essential.[1] Sex estimation is one of the most used parameters for the initial identification of missing persons, consisting of one of the most important assignments of forensic anthropologists and physicists.[2,3] Some structures are used to estimate individual characteristics, such as the bones of the skull, pelvis, and femur. The sella turcica, mastoid cells, and paranasal sinuses also help the identification process.[4]

Located in the bones that compose the nasal cavity, paranasal sinuses are classified according to anatomical relationships into maxillary sinuses (MS), ethmoid sinuses (ES), frontal sinuses (FS), and sphenoid sinuses (SS).[5-7] Such structures present great morphological diversity, such as the SS, which are so different and unique that it is highly unlikely that two individuals would have the same morphology[3], and they may be valuable for identification.[8]

Different radiological exams such as radiographs, computed tomography (CT), cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI), among others, can be used to analyze paranasal sinuses and perform human identification.[9-12] However, CBCT has recently become a suitable imaging method for exploring sinuses.[13]

The literature is still limited on validating SS as an alternative in the field of Forensics, mainly regarding Brazilian population. Thus, this study aimed to perform linear (two-dimensional) SS measurements using CBCT images from Brazilian individuals and analyze the influence of sex, age, skin color, and nutritional status with the body mass index (BMI), verifying potential differences between the right and left sides. This is the first study that assesses the influence of skin color and nutritional status on SS linear measurements.

2. Material and Methods

This project was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University - Unesp (CAAE - nº 47706121.4.0000.5416). The CBCT images were obtained from an image bank owned by one of the researchers. The identity of individuals remained confidential, maintaining their privacy. Images of SS showing changes due to malformations, obliterations, pathologies, and/or trauma were not included.

A total of 238 head and neck CBCT images of live Brazilian subjects of both sexes (139 women and 99 men), aged between 6 and 68 years, were used. This study also analyzed the variables of skin color and nutritional status with the body mass index (BMI). However, not all variables were considered for all individuals, as some did not present complete data.

The following age groups were considered: 6 to 11 years (n=49), 12 to 17 years (n=69), and 18 years or older (118 adults). Regarding skin color, 182 individuals were white, and 47 were black. The BMI was calculated with the following formula: BMI = weight/height^2. The sample consisted of 58 individuals with a normal BMI (between 18.5 and 24.9) and 61 with BMI above normal (above 25).[14] Table 1 describes the classification of categories and the number of variables.

The CBCT protocol was obtained with the i-CAT device, making the images available in DICOM (Digital Imaging and Communications in Medicine) language. These images had a maximum field of view covering the entire head region, and cropped images were discarded. This study used the DDS-Pro™ 2.12.0_2021 software (DPP Systems, Czestochowa, Poland) to visualize and perform the linear measurements.

Two examiners measured the height, width, and depth for analyzing accuracy and reproducibility, with at least seven days between the first and second measurements. In all images, linear height and width measurements were taken in the coronal slice (Figure 1), and depth measurements were taken in the sagittal slice (Figure 2). Additionally, the maximum opening of the sinus was considered for all the measurements (width, height, and depth). The SS not visualized and/or with some pathology were not measured. The maximum opening of the sinus in the measurements of width and height should consider the midline that divides the right side from the left (Figure 3).

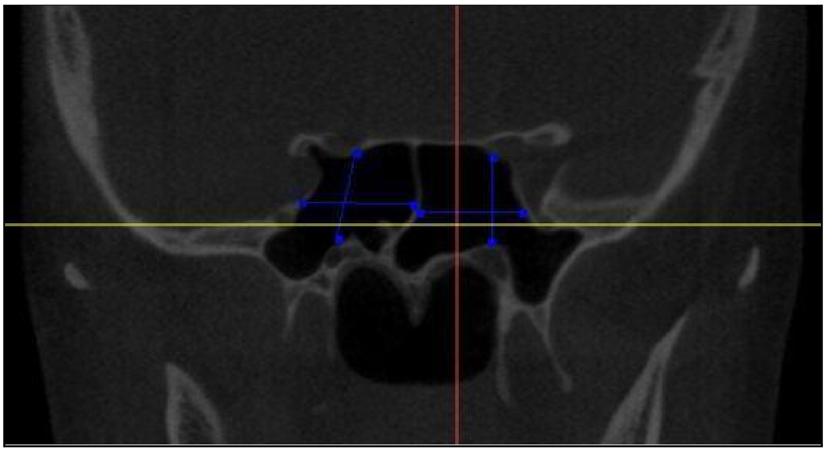

Figure 1 Linear measurements (height and width) of the sphenoid sinus in the coronal plane
Source: Own elaboration.

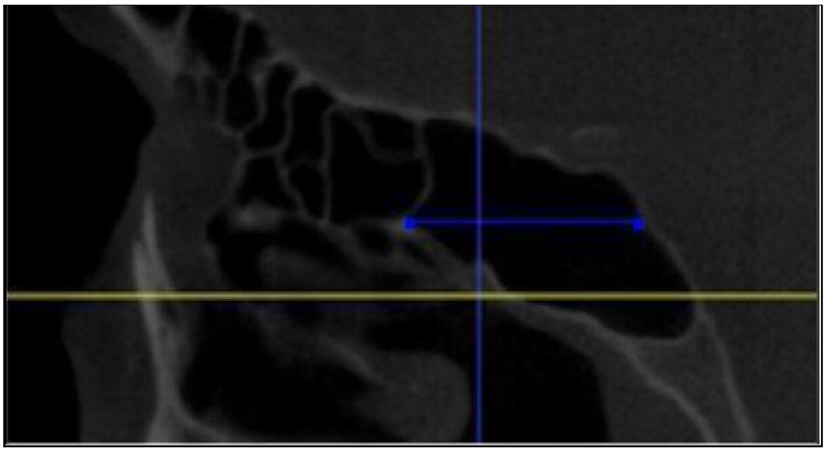

Figure 2 Linear measurement (depth) of the sphenoid sinus in the sagittal plane
Source: Own elaboration.

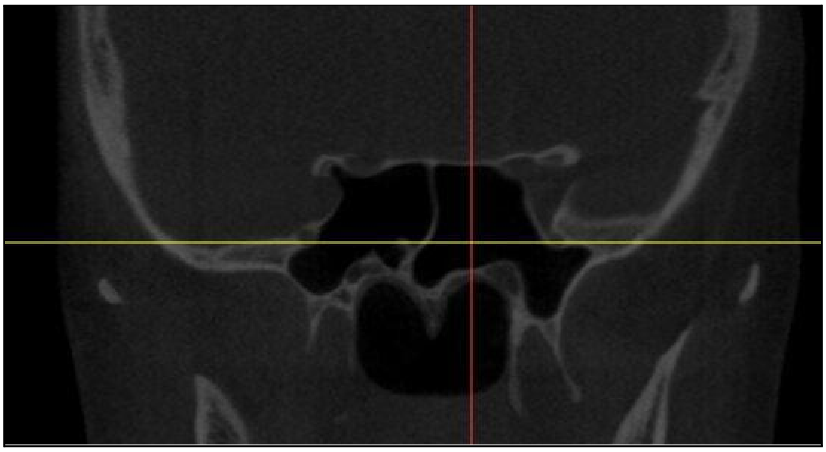

Figure 3 Location of the maximum opening of the sphenoid sinus in the coronal plane, considering the midline that divides the left and right sides
Source: Own elaboration.

2.1 Statistical analysis

The inter- and intra-examiner reproducibility of measurements was evaluated with TEM (technical error of measurement), rTEM (relative technical error of measurement), and R (coefficient of reliability). The measurement data were subjected to descriptive and exploratory analyses, followed by paired t-tests to compare the left and right sides. The means of the left and right sides of each participant were calculated and new descriptive and exploratory analyses were performed on these values. Student's t-test was used for comparisons in cases of two categories (sex, skin color, and BMI). Analysis of variance (ANOVA) was used for the three age groups. However, generalized linear models were used for all variables when the data did not meet the test assumptions. The measurement means were also estimated with 95% confidence intervals corresponding to sex and age group. All analyses were performed with the R software at a 5% significance level.[15]

3. Results

Table 1 shows that 58.4% of the sample were women and 41.6% were men. Also, 49.6% were 18 years or older, 20.6% were 6 to 11 years old, and 29.0% were 12 to 17 years old. The skin color of 76.5% of the sample was white.

Table 1 Profile of the sample studied (n=238)

Variable	*Category*	*Frequency (%)*
Sex	Female	139 (58,4%)
	Male	99 (41,6%)
Age group (years)	From 6 to 11	49 (20,6%)
	From 12 to 17	69 (29,0%)
	18 or older	118 (49,6%)
	No information	2 (0,8%)
Skin color	White	182 (76,5%)
	Black	47 (19,5%)
	No information	9 (3,8%)
BMI	Normal	58 (24,4%)
	Above normal	61 (25,6%)
	No information	119 (50,0%)

BMI = Body Mass Index.

Table 2 presents the results of the analyses of measurement reproducibility (intra- and inter-examiner).

Table 2 Results of the analyses of inter- and intra-examiner errors in measurements (n=30)

Variable	*Side*	*Intra-examiner*			*Inter-examiner*		
		TEM	*rTEM*	*R*	*TEM*	*rTEM*	*R*
Sphenoid sinus height	Left	0,196	1,109	0,998	0,275	1,554	0,996
	Right	0,194	1,120	0,997	0,262	1,511	0,995
Sphenoid sinus width	Left	0,192	1,179	0,998	0,262	1,607	0,997
	Right	0,209	1,430	0,998	0,279	1,910	0,997
Sphenoid sinus depth	Left	0,183	0,792	0,999	0,263	1,138	0,998
	Right	0,193	0,957	0,999	0,304	1,501	0,998

TEM: technical error of measurement; rTEM: relative technical error of measurement; R: coefficient of reliability.

Table 3 and Figure 4 present the results of the comparisons between measurements on the left and right sides. There were no significant differences between the sides.

Table 3 Results of the analyses of sides comparisons (mm)

Variable	*Side*				*Difference between the sides*		[1]*p-value*
	Left		*Right*				
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus height	17,78 (4,15) A	18,00 (5,40; 28,70)	18,23 (3,96) A	18,20 (6,90; 29,90)	0,45 (4,75)	0,60 (-13,20; 17,40)	0,1477
Sphenoid sinus width	15,18 (5,36) A	14,50 (5,10; 38,40)	15,23 (4,71) A	14,40 (6,30; 33,20)	0,04 (6,85)	0,20 (-21,70; 23,40)	0,9289
Sphenoid sinus depth	20,82 (6,81) A	20,20 (3,40; 38,40)	20,72 (6,35) A	20,70 (5,60; 35,60)	-0,10 (8,86)	0,00 (-23,40; 23,40)	0,8675

[1]Paired t-test. Distinct horizontal letters indicate significant differences between sides ($p \leq 0.05$).

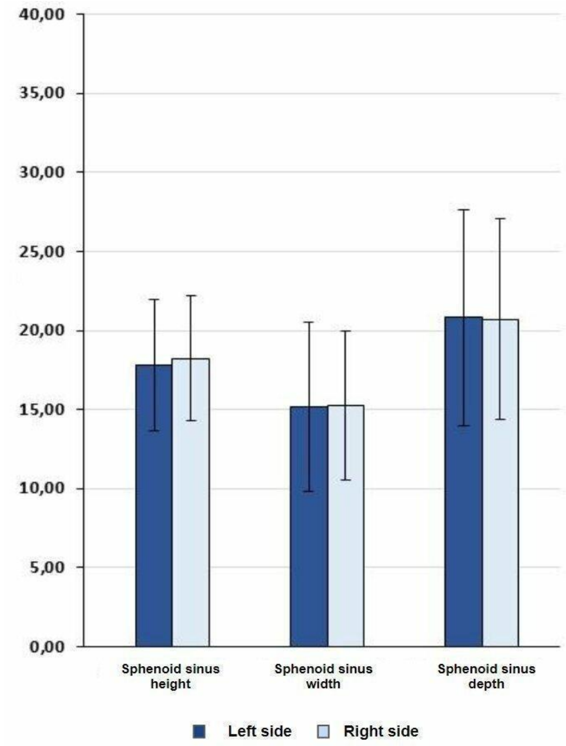

Figure 4 Mean and standard deviation of measurements of the height, width and depth of the sphenoid sinus (mm), regarding side.

In the measurement comparisons between the sexes (Table 4 and Figure 5), men showed higher values than women in all measurements, but SS height was significantly greater in men ($p<0.05$).

Table 4 Results of the analyses of sexes comparisons (mm)

Variable	*Sex*				*p-value*
	Female		*Male*		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus height	17,47 (3,05) B	17,38 (9,55; 26,25)	18,73 (3,48) A	18,90 (10,00; 27,40)	[1]0,0039
Sphenoid sinus width	14,96 (3,41) A	14,40 (8,70; 28,35)	15,54 (4,07) A	14,95 (9,70; 34,95)	[2]0,1979
Sphenoid sinus depth	20,58 (4,83) A	20,55 (6,65; 33,3)	21,03 (4,93) A	21,20 (11,75; 34,05)	[2]0,5001

[1]Student's t-test t; [2]Generalized linear model. Distinct horizontal letters indicate significant differences between sexes ($p \leq 0.05$).

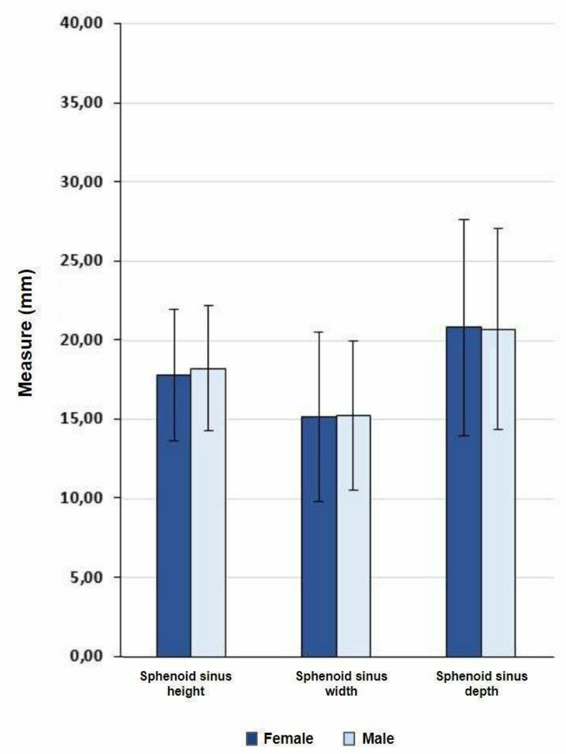

Figure 5 Mean and standard deviation of measurements of the height, width and depth of the sphenoid sinus (mm), regarding sex

The comparison of different age groups (Table 5 and Figure 6) did not show significant difference for SS height (p>0.05). The SS width and depth were significantly greater in 18 years or older than from 6 to 11 years old (p<0.05).

Table 5 Results of the analysis of comparisons between age groups (mm)

Variable	*Age group (years)*						*p-value*
	6 to 11		*12 to 17*		*18 and older*		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus height	17,52 (3,17) A	17,30 (11,75; 27,40)	18,22 (3,30) A	17,95 (10,55; 26,80)	18,10 (3,34) A	18,23 (9,55; 25,60)	[2]0,4936
Sphenoid sinus width	13,82 (3,40) B	13,05 (8,70; 27,55)	15,01 (2,93) A	14,70 (10,15; 25,75)	15,94 (4,05) A	15,08 (8,85; 34,95)	[2]0,0008
Sphenoid sinus depth	17,91 (4,63) B	17,90 (6,65; 27,55)	20,66 (4,32) A	20,85 (10,90; 30,00)	22,09 (4,76) A	21,88 (11,55; 34,05)	[1]<0,0001

[1]Analysis of variance (ANOVA); [2]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups (p≤0.05).

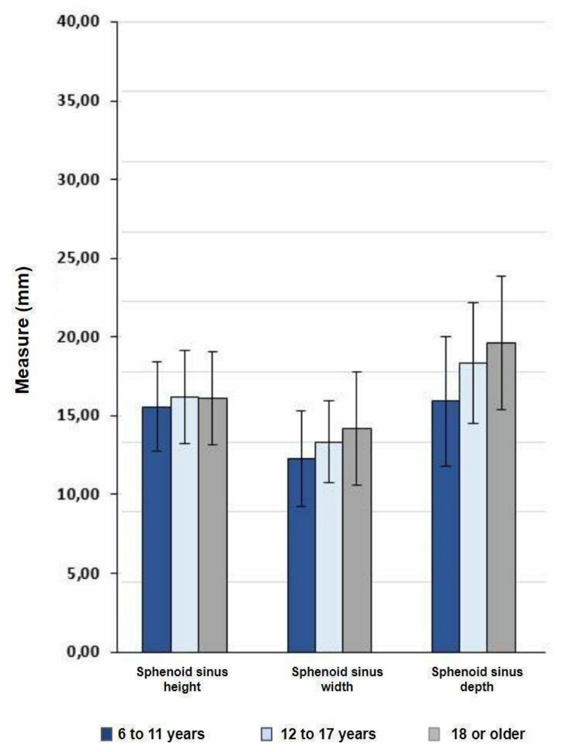

Figure 6 Mean and standard deviation of measurements of the height, width and depth of the sphenoid sinus (mm), regarding age group.

There was no significant difference in the measurements for skin color and BMI ($p>0.05$), as seen in Tables 6 and 7. Table 8 shows the estimates of each measure with the respective 95% confidence interval regarding sex and age group.

Table 6 Results of the analyses of skin color comparisons (mm)

Variable	*Skin color*				[1]*p-value*
	White		*Black*		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus height	18,03 (3,27) A	18,00 (9,55; 27,40)	18,11 (3,25) A	18,15 (10,65; 26,45)	0,8838
Sphenoid sinus width	15,44 (3,94) A	14,70 (8,70; 34,95)	14,53 (2,64) A	14,75 (9,70; 20,15)	0,1128
Sphenoid sinus depth	20,92 (4,98) A	21,05 (6,65; 34,05)	20,22 (4,54) A	21,05 (11,55; 28,80)	0,4100

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between skin color ($p \leq 0.05$).

Table 7 Results of analyses of BMI categories comparisons (mm)

Variable	*BMI*				[1]*p-value*
	Normal		*Above normal*		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Sphenoid sinus height	17,88 (3,47) A	17,83 (10,00; 27,40)	18,26 (2,61) A	18,15 (12,15; 25,60)	0,5168
Sphenoid sinus width	15,57 (4,30) A	15,13 (8,85; 34,95)	14,72 (3,53) A	14,23 (9,80; 30,50)	0,1983
Sphenoid sinus depth	21,72 (4,91) A	21,98 (12,25; 34,05)	19,98 (4,78) A	20,23 (7,55; 32,00)	0,0623

[1]Generalized linear model.

Table 8 Estimation of maxillary sinus linear measurements (mm) for sexes and age groups

Variable	Sex	Age group (years)					
		6 to 11		12 to 17		18 and older	
		Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%	Mean (standard deviation)	CI95%
Sphenoid sinus height	Female	17 (2,44)	16,01 - 17,99	17,20 (3,17)	16,07 - 18,32	17,76 (3,19)	17,03 - 18,49
	Male	18,13 (3,83)	16,43 - 19,82	19,27 (3,13)	18,14 - 20,40	18,73 (3,55)	17,61 - 19,85
Sphenoid sinus width	Female	13,35 (2,51)	12,33 - 14,36	15,18 (3,33)	14,00 - 16,36	15,42 (3,58)	14,60 - 16,24
	Male	14,39 (4,21)	12,52 - 16,25	14,84 (2,48)	13,95 - 15,73	16,90 (4,69)	15,41 - 18,38
Sphenoid sinus depth	Female	18,31 (5,10)	16,25 - 20,37	20,26 (4,51)	18,66 - 21,86	21,51 (4,64)	20,44 - 22,58
	Male	17,45 (4,07)	15,64 - 19,25	21,08 (4,15)	19,59 - 22,58	23,14 (4,86)	21,60 - 24,67

CI: Confidence interval

4. Discussion and Conclusion

Some expert investigations seek to establish human identity with identification methods. Thus, in the Forensic field, identity is defined as the set of physical, psychological, functional, and civil characteristics that individualize a person, making them unique and different from others. However, establishing an identity and distinguishing a person from others requires techniques or methods, namely identification.[16,17] Human identity has always played an important role in assisting society, and it has long been a focus of attention.[18]

Computed tomography (CT) is the recommended exam for analyzing the morphology of paranasal sinuses because it is an imaging exam with advantages such as higher resolution, three-dimensional scanning, no element overlapping, and accurate measurements.[10,19] Thus, the particularities of the contours of paranasal sinuses are valuable to Forensic Sciences and can be used as an identification method because their images can determine the human identity.[20-23]

This study performed SS linear measurements (height, width, and depth) from CBCT images and analyzed potential differences between the sides (left and right) and measurement correlations to sex, age, skin color, and nutritional status (BMI). There are no studies in the literature including all these analyses that allow establishing comparisons with the data obtained in this study. This research was developed with a Brazilian sample but there is a scarcity of reports in the literature about the applicability of SS measures considering such variables.

In anthropometry, Technical Error Measurement (TEM) is the most used technique to control the quality of measurements and show the margin of error, verifying the degree of accuracy of repeated measurements (intra-examiner) and comparing them with the measurements of another examiner (inter-examiner).[24,25] The TEM and rTEM results obtained in this study for the three measurements, both intra- and inter-examiner, and R values confirmed data reliability and indicated excellent precision and reproducibility of measurements, considering that R values were very close to one.

This study did not show significant differences between the left and right sides for any measurements. Wu et al.[26] studied SS anatomical features by measuring some distances in a sample of 89 Chinese adults using sagittal CT reconstruction images and did not find significant differences between the right and left sides in any parameter measured.

However, Sherif et al.[27], studying a sample of adult Egyptian subjects using multidetector CT, observed that women did not show significant differences between the two sides. However, there was a significant difference between the sides in the horizontal distance from the anterior SS wall to the lowest point of the sella and depth values for men, with a higher value on the right side. Similarly, Kaplanoglu et al.[28] determined specific SS measurements for the Turkish population using sagittal CT reconstruction images and, according to the authors, the horizontal distance from the anterior SS wall to the lowest point of the sella and the horizontal distance from the anterior SS wall to the posterior SS wall were greater on the left side than on the right side. There was no significant difference between the right and left sides for men, and the left side values were higher in women.

Kajoak et al.[29], studying a sample of Sudanese individuals, obtained similar results when determining the anatomical characteristics of SS using CT with seven horizontal and vertical linear measurements. According to the authors, there was no statistically significant difference in the length of line 1 (distance to the roof of the SS) between men and women on both sides, but there was a significant difference between the sexes on the left side in line 2 (distance to the bottom of the SS), which was greater in men than in women. There was a significant difference between the sexes on the right and left sides in line 3 (distance to the posterior SS wall) when located below the sella (greater in men on the right side), but there was no significant difference between men and women on the right and left sides when located over the sella. There was also a statistically significant difference in the length of line 4 (distance from the bottom of the sella to the anterior SS wall) between the sexes on both right and left sides (greater in women). Furthermore, there was no statistically significant difference in the length of line 5 (distance from the base of the skull from the anterior SS wall to the sella) between the sexes on either side. Line 6 (maximum depth) showed a significant difference between men and women on the right and left sides (greater in men on the left side) and a significant difference between men and women on the left side in line 7 (maximum width) (greater in men).

There are differences in SS size between men and women, meaning that differences between the sexes must be considered in SS procedures.

In this study, SS height was significantly greater in men ($p<0.05$), but the other parameters did not show significant differences between the sexes. Demiralp et al.[30], using a sample of 32 ancient skulls from Turkey, measured the width and height of paranasal sinuses with CBCT. According to the authors, the distance from the anteroposterior SS wall in axial sections was greater in men ($p>0.05$). Kaplanoglu et al.[28] also found differences between the sexes in the Turkish population, in which lines 2, 3, 4, and 6 (respectively: vertical distance from the SS ostium to the lowest point of the sinus base, the horizontal distance from the center of the SS ostium to the posterior sinus wall, the horizontal distance from the anterior SS wall to the lowest point of the sella, and greatest horizontal distance from the anterior SS wall to the posterior wall) were longer in men than in women, concluding that sexual dimorphism should be considered in SS surgical procedures.

However, Ramos et al.[31] evaluated, with CBCT, the possibility of estimating sex in a Brazilian population through SS measurements, and the results did not suggest statistically significant differences in the measurements between men and women.

This study did not show significant differences between age groups for SS height ($p>0.05$). For individuals 18 years or older, the width and depth of the sinus were significantly greater than in the age group of 6 to 11 years ($p<0.05$). However, Demiralp et al. (2019) conducted a study with CBCT to verify the potential use of the width and height of paranasal sinuses to estimate sex and age. The sample was divided into three age groups: 21-40 years, 41-60 years, and 61-80 years. The results did not show significant differences in height ($p=0.079$), width ($p=0.273$), and distance from the anteroposterior SS wall ($p=0.329$) regarding age.

However, when considering sexual dimorphism and age through linear SS measurements, there is a scarcity of studies in the literature. Therefore, the results described in this study can be the starting point for further research and evaluations in this field regarding linear SS measurements. There are also no data published so far in the literature analyzing the influence of skin color and nutritional status on SS measurements, which did not allow determining comparison parameters.

Regarding skin color (white and black) and BMI (normal or above normal), there were no significant differences in any SS measurements ($p>0.05$). The available data did allow demonstrating a relationship between the factors measured. However, further studies are required.

The estimates of each measure with the respective 95% confidence interval according to sex and age group obtained in this study can contribute to Forensic Sciences and consequently assist Justice and society.

The results of the present study did not show significant differences between the sides of the SS, but there was an anatomical variability between the sexes, with men showing significantly higher values than women for SS height. However, the other measures did not show significant differences between the sexes. Thus, SS height may help Forensic Sciences determine sexual dimorphism. There were also significant differences between age groups, but no significant differences in the measurements for skin color and nutritional status. However, further studies are required.

Ethical approval

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University (Unesp).

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Conflicts of interest

There are no conflicts of interest.

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3.7 Publicação 7[7*]

A morphometric study of CBCT images of the frontal sinus in a Brazilian population[1]

Abstract

The morphometric characteristics of frontal sinuses are unique for each individual and important for the Forensic field, especially for human identification. There are few studies with CBCT analyses, especially with the Brazilian population. In this study, the height, width, and depth of frontal sinuses (FS) were measured, from CBCT images of 238 living Brazilian subjects.The study verified potential significant differences (p>0.05) between the right and left sides and related to sex, age, skin color, and nutritional status using the body mass index (BMI). There were differences between the sides, with significantly higher measurements on the left side for FS depth. Both FS width and depth were greater (p>0.05) in men. All measurements were significantly higher in 18 years or older than from 6 to 11 years old (p<0.05), and FS height and depth were also significantly higher in 18 years or older than from 12 to 17 years old. (p<0.05). The measurements did not show significant differences in skin color and BMI. The estimates presented for each measure based on sex and age group can be used as a reference in cases requiring sex or age estimation of Brazilian individuals.

KEYWORDS

Radiological anatomy. Human identification. Forensic anatomy. Forensic anthropology. Forensic dentistry.

INTRODUCTION

The main purpose of the identification process is to verify the identity of an individual. Identity is defined as the set of physical, functional or psychological, normal or pathological characteristics that qualify the individual as identical only to himself [1,2]. However, the methods and techniques that individualize a person and make them unique are called identification. This is a complex, systematic, and organized process consisting of a conscious comparison of the data from an individual with the corresponding data of the subject to be identified [1-9].

[7*] Artigo descrito segundo as normas do periódico *European Journal of Oral Sciences*.

[1] O material e métodos deste estudo foram obtidos do trabalho de tese de doutorado da própria autora.

The contribution of Forensic Dentistry to the process of human identification is essential because it provides a series of information for adequate identification, and using dental records in Forensic Sciences is a reliable, practical, fast, and inexpensive identification method [2,10-12]. Consequently, the comparative analysis of *ante-mortem* and *post-mortem* images, mainly of frontal sinuses (FS), has been a remarkable method for forensics due to its numerous anatomical characteristics. It is also considered an immutable structure, although certain pathological processes may change it. Moreover, like fingerprints, FS are bilateral structures unique to each individual, even among identical twins, and can be used for human identification [5,13,14].

The morphometric characteristics of frontal sinuses are unique for each individual and important in the Forensic field, especially in the search for human identification. These anatomical structures can also help determine the biological profile of individuals, especially in sex and age estimations.

The literature shows studies on the use of frontal sinuses for human identification, mainly from the analysis of radiographic images. However, Cone-Beam Computed Tomography (CBCT) provides better resolution than traditional radiographs, allowing higher precision in the analyses [7,15,16]. There are few anatomical studies of FS using CBCT. This study aimed to perform linear measurements of FS height, width, and depth in a sample of Brazilian individuals using Cone-Beam Computed Tomography (CBCT) images, analyze the influence of sex, age, skin color, and nutritional status (body mass index - BMI), and verify potential differences between the right and left sides.

MATERIALS AND METHODS

All CBCT images in this study were obtained from an image bank owned by one of the researchers. The identity of the individuals remained confidential.

Thus study used a sample of 238 head and neck CBCT images of living Brazilian subjects, including 139 women, 99 men, aged between 6 and 68 years, 182 white subjects, and 47 black subjects. The following age groups were established: from 6 to 11 years (n = 49), 12 and 17 years (n = 69), and 18 years or older (n = 118).

Nutritional status was analyzed with the BMI. The sample presented 58 subjects with normal BMI (18.5 and 24.9) and 61 with BMI above normal (BMI above 25) [17]. The BMI was calculated using the following formula: BMI = weight/height^2.

The images were made available in DICOM (Digital Imaging and Communications in Medicine) format and obtained with an i-CAT cone-beam tomograph. The DDS-Pro 2.12.0_2021 software (DPP Systems, Czestochowa, Poland) was used to visualize and measure the sinus. In all images, height and width were measured in coronal view and depth in sagittal view (Figures 1-2). Two examiners performed measurements to verify reproducibility, with a minimum interval of seven days.

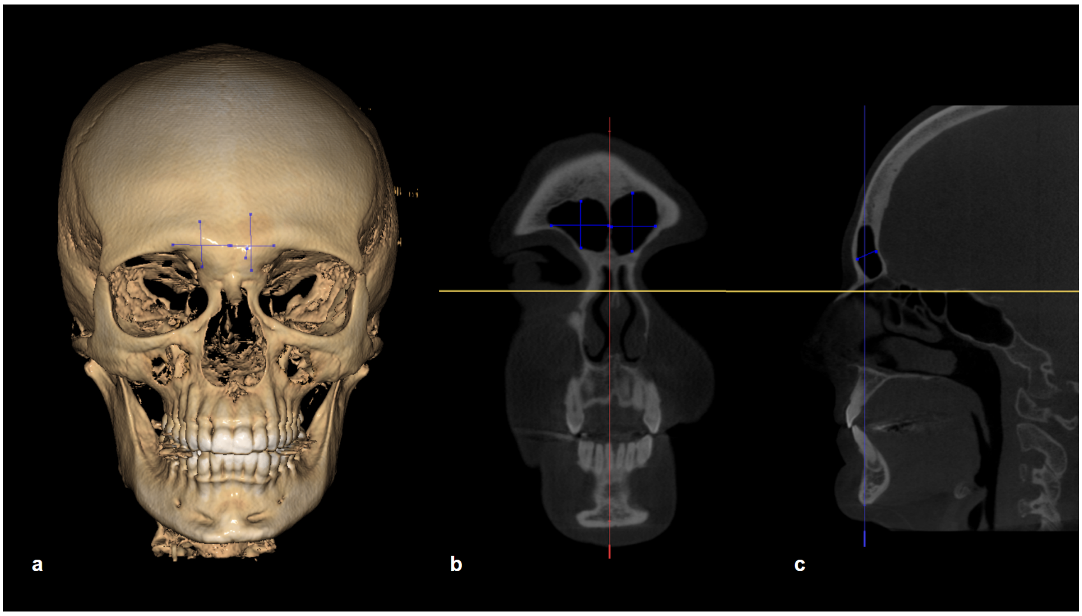

Fig. 1 a. 3D reconstructed skull showing linear measurements of a frontal sinus. b. CBCT measurements in the coronal plane. c. CBCT measurements in the sagittal plane. Source: Own elaboration.

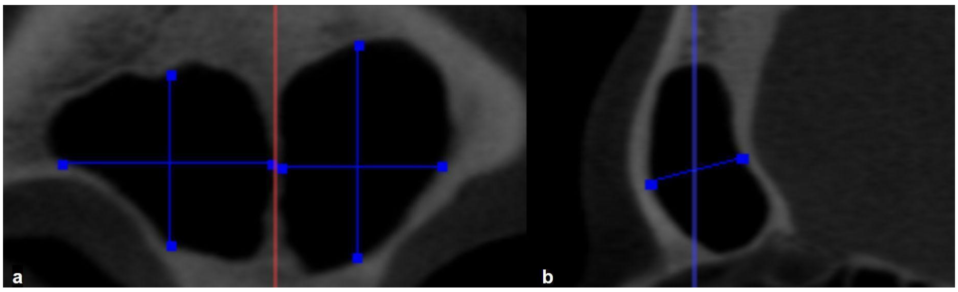

Fig. 2 Frontal sinus linear measurements on a CBCT, using DDS-Pro™ software. a. Height and width in the coronal plane. b. Depth in the sagittal plane. Source: Own elaboration.

The FS with pathologies, obliterations, malformations, and/or traumas were excluded from this study. The FS of the right and left sides of all individuals were measured. When one of the sinuses presented some exclusion factor, then only the FS without changes was measured.

Regarding the inter- and intra-examiner analyses, the reproducibility of measurements was evaluated with TEM (technical error of measurement), rTEM (relative technical error of measurement), and R (coefficient of reliability) values, which are the most common ways of expressing the margin of error in anthropometry. The data were subjected to descriptive and exploratory analyses, followed by paired t-tests to compare the left and right sides. For each participant, the means of the left and right sides were calculated and new descriptive and exploratory analyses were performed on these means. Student's t-test was used for comparisons in cases of two categories (gender, skin color, and BMI). Analysis of variance (ANOVA) was used for the three age groups. When the data did not meet the test assumptions, generalized linear models were used for all variables. The measurement means were also estimated with 95% confidence intervals corresponding to sex and age group. All analyses were performed with the R software at a 5% significance level [18].

RESULTS

Table 1 shows that 58.4% of the sample were women and 41.6% were men. Also, 49.6% were 18 years or older, 20.6% were 6 to 11 years old, and 29.0% were 12 to 17 years old. As for skin color, 76.5% of the sample was composed of white subjects.

TABLE 1 Profile of the sample studied (n=238).

Variable	Category	Frequency (%)
Sex	Female	139 (58,4%)
	Male	99 (41,6%)
Age group (years)	From 6 to 11	49 (20,6%)
	From 12 to 17	69 (29,0%)
	18 or older	118 (49,6%)
	No information	2 (0,8%)
Skin color	White	182 (76,5%)
	Black	47 (19,5%)
	No information	9 (3,8%)
BMI	Normal	58 (24,4%)
	Above normal	61 (25,6%)
	No information	119 (50,0%)

BMI – Body mass index.

Table 2 presents the results of the analysis of measurement reproducibility (intra- and inter-examiner).

TABLE 2 Results of the analyses of inter- and intra-examiner errors in measurements (n=30).

Variable	Side	Intra-examiner			Inter-examiner		
		TEM	rTEM	R	TEM	rTEM	R
Frontal sinus height	Left	0,181	0,919	0,999	0,253	1,287	0,999
	Right	0,189	0,929	1,000	0,274	1,348	0,999
Frontal sinus width	Left	0,225	1,298	0,998	0,283	1,633	0,997
	Right	0,192	1,033	0,999	0,297	1,595	0,997
Frontal sinus depth	Left	0,170	1,866	0,996	0,224	2,460	0,993
	Right	0,148	1,761	0,997	0,182	2,163	0,995

TEM: technical error of measurement; rTEM: relative technical error of measurement; R: coefficient of reliability.

Table 3 and Figure 3 present the results of the comparisons between measurements on the left and right sides. For sinus height and width, the right side showed higher values, but there were no significant differences (p>0.05). For FS depth, measurements were significantly higher on the left side (p<0.05), with a mean variation of 0.80 mm. In this case, there was a variation from -6.60 mm (larger left side) to 9.60 mm (larger right side). There were no significant differences for sinus depth (p>0.05).

TABLE 3 Results of the analyses of sides comparisons (mm).

Variable	Side				Difference between the sides		[1]p-value
	Left		Right				
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Frontal sinus height	17,67 (7,46) A	17,15 (3,50; 41,80)	17,68 (8,54) A	16,30 (4,40; 40,30)	-0,33 (7,02)	-0,90 (-22,30; 29,30)	0,4934
Frontal sinus width	18,98 (6,33) A	18,85 (6,90; 40,40)	19,39 (7,75) A	19,10 (3,20; 41,50)	0,32 (9,20)	0,15 (-32,00; 21,80)	0,6132
Frontal sinus depth	9,13 (2,92) A	8,65 (3,50; 20,50)	8,44 (2,66) B	8,10 (3,60; 17,50)	-0,80 (2,23)	-0,85 (-6,60; 9,60)	<0,0001

[1]Paired t-test. Distinct horizontal letters indicate significant differences between sides (p≤0.05).

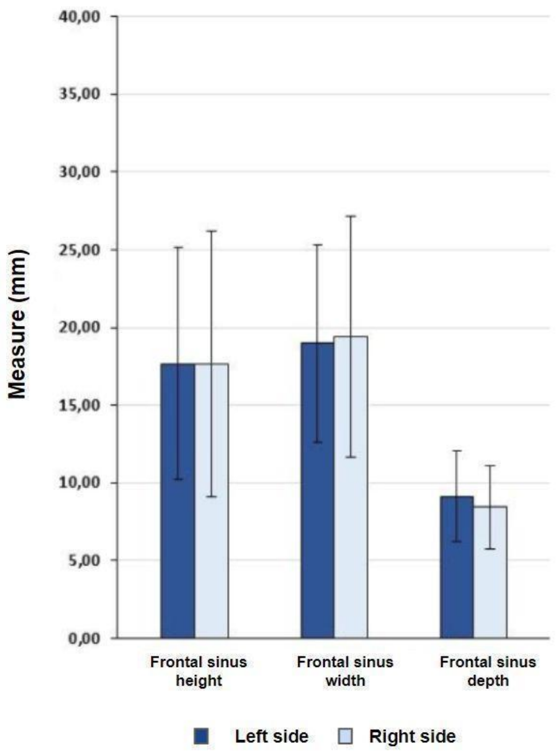

FIGURE 3 Mean and standard deviation of measurements of the height, width and depth of the frontal sinus (mm), regarding side. The values are defined in Table 3.

The comparison between the sexes (Table 4 and Figure 4) showed higher values for men than for women in all measures, but only FS width and depth were significantly higher in men (p<0 .05).

TABLE 4 Results of the analyses of sexes comparisons (mm).

Variable	Sex				p-value
	Female		Male		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Frontal sinus height	17,00 (7,17) A	16,23 (4,90; 39,50)	18,23 (7,35) A	17,10 (5,85; 37,00)	[1]0,2140
Frontal sinus width	18,27 (4,81) B	18,05 (6,60; 30,45)	20,32 (5,98) A	19,35 (8,75; 37,25)	[1]0,0053
Frontal sinus depth	8,01 (1,91) B	8,13 (4,15; 12,80)	9,78 (3,00) A	9,10 (4,80; 18,60)	[2]<0,0001

[1]Student's t-test t; [2]Generalized linear model. Distinct horizontal letters indicate significant differences between sexes (p≤0.05).

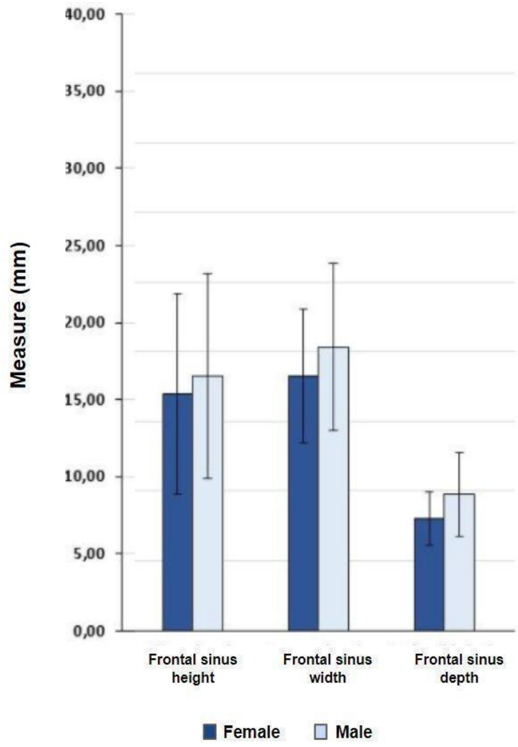

FIGURE 4 Mean and standard deviation of measurements of the height, width and depth of the frontal sinus (mm), regarding side. The values are defined in Table 4.

Regarding age, all measurements were significantly higher in 18 years or older than from 6 to 11-years old ($p<0.05$). The FS height and depth were also significantly higher in 18 years or older than from 12 to 17 years old ($p<0.05$) (Table 5 and Figure 5).

TABLE 5 Results of the analysis of comparisons between age groups (mm).

Variable	Age group (years)						[1]p-value
	6 to 11		12 to 17		18 and older		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Frontal sinus height	14,39 (6,53) B	13,28 (4,90; 31,90)	15,80 (6,06) B	15,00 (6,25; 30,65)	19,61 (7,54) A	19,55 (4,95; 39,50)	<0,0001
Frontal sinus width	17,47 (4,28) B	17,80 (6,60; 27,85)	18,63 (5,18) AB	18,20 (9,00; 31,90)	20,02 (5,77) A	19,20 (8,75; 37,25)	0,0201
Frontal sinus depth	7,83 (2,40) B	7,98 (4,30; 18,60)	8,38 (2,12) B	8,30 (4,35; 17,30)	9,28 (2,75) A	8,70 (4,15; 17,05)	0,0014

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between age groups (p≤0.05).

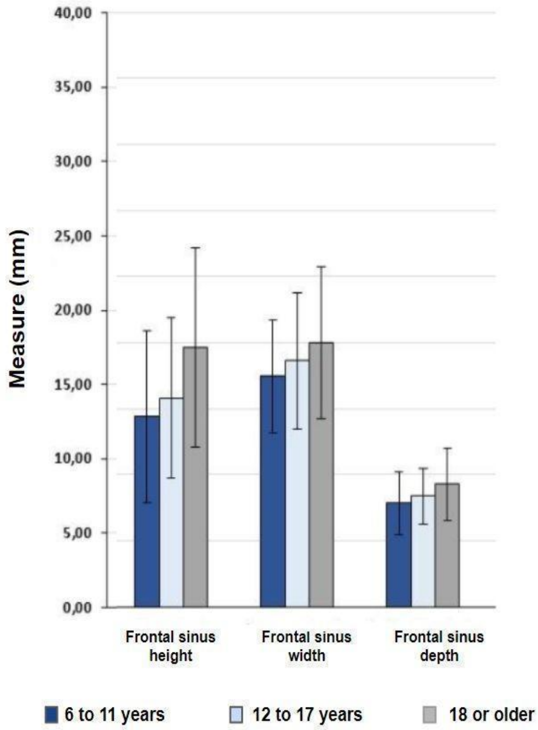

FIGURE 5 Mean and standard deviation of measurements of the height, width and depth of the frontal sinus (mm), regarding age group. The values are defined in Table 5.

There was no significant difference in the measurements for skin color and BMI (p>0.05) (Tables 6 and 7).

TABLE 6 Results of the analyses of skin color comparisons (mm).

Variable	Skin color				[1]p-value
	White		Black		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Frontal sinus height	17,54 (7,20) A	17,00 (4,90; 39,50)	16,48 (6,80) A	16,03 (6,05; 31,10)	0,3796
Frontal sinus width	18,94 (5,30) A	18,30 (8,75; 37,25)	19,37 (5,70) A	19,40 (6,60; 31,90)	0,6383
Frontal sinus depth	8,72 (2,47) A	8,40 (4,15; 18,60)	8,53 (2,55) A	8,10 (4,80; 17,30)	0,6295

[1]Generalized linear model. Distinct horizontal letters indicate significant differences between skin color ($p \leq 0.05$).

TABLE 7 Results of analyses of BMI categories comparisons (mm).

Variable	BMI				[1]p-value
	Normal		Above normal		
	Mean (standard deviation)	Median (minimum and maximum values)	Mean (standard deviation)	Median (minimum and maximum values)	
Frontal sinus height	17,62 (8,04) A	17,50 (4,95; 39,50)	17,08 (6,50) A	17,00 (7,05; 35,65)	0,6987
Frontal sinus width	19,29 (5,41) A	18,40 (10,80; 32,15)	19,30 (5,63) A	18,30 (6,60; 37,25)	0,9916
Frontal sinus depth	8,82 (2,71) A	8,40 (4,15; 17,30)	8,54 (2,12) A	8,30 (4,50; 15,05)	0,5275

[1]Generalized linear model. BMI = Body Mass Index.

Table 8 shows the estimates of each measure with the respective 95% confidence interval according to sex and age group.

TABLE 8 Estimation of maxillary sinus linear measurements (mm) for sexes and age groups

Variable	**Sex**	**Age group (years)**					
		6 to 11		**12 to 17**		**18 and older**	
		Mean (standard deviation)	**CI95%**	**Mean (standard deviation)**	**CI95%**	**Mean (standard deviation)**	**CI95%**
Frontal sinus height	Female	14,26 (6,67)	11,37 - 17,14	15,12 (6,7)	12,74 - 17,49	18,69 (7,14)	17,04 - 20,35
	Male	14,55 (6,54)	11,39 - 17,70	16,52 (5,32)	14,6 - 18,44	21,35 (8,06)	18,74 - 23,96
Frontal sinus width	Female	16,69 (4,29)	14,83 - 18,55	18,70 (5,21)	16,85 - 20,54	18,57 (4,74)	17,48 - 19,67
	Male	18,42 (4,18)	16,41 - 20,43	18,57 (5,23)	16,68 - 20,45	22,77 (6,58)	20,64 - 24,9
Frontal sinus depth	Female	7,20 (1,61)	6,51 - 7,90	7,79 (1,62)	7,21 - 8,36	8,36 (2,04)	7,89 - 8,83
	Male	8,58 (2,98)	7,15 - 10,02	9,00 (2,41)	8,13 - 9,86	11,04 (3,08)	10,05 - 12,04

CI: Confidence interval

DISCUSSION

Although frontal sinuses (FS) have been studied with interest in radiology and anthropology since the 1920s, their usefulness for positive cadaver identification has recently been emphasized [19]. It is scientifically proven that FS are unique to each individual and unaffected by ancestry [20,21], and their anatomical particularities can be the basis for forensic identification [21-24]. Currently, using FS to identify unknown bodies is a reliable technique used in the presence of *ante-mortem* records, and can be presented as evidence in a court of law [23,25-27]. Several authors have proposed different FS identification methods with imaging exams [27,28-31].

This study measured FS height, width, and depth with CBCT images and verified potential differences between the left and right sides. The study also analyzed the correlation to sex, age, skin color, and nutritional status (BMI). There were no studies in the literature evaluating all these variables, therefore, it was impossible to establish comparisons with the data obtained in this study.

Technical Error Measurement (TEM) is the most used technique to control the reproducibility and accuracy of measurements and demonstrate anthropometric error margins, thus verifying the accuracy of duplicate measurements (intra-examiner) and comparing measurements with another examiner (inter-examiner) [4,32]. The intra- and inter-examiner TEM and rTEM results in this study, for the three measurements, and R values, confirm data reliability and show excellent precision and reproducibility of measurements, as the R values were very close to one.

The present study found statistically significant asymmetry between the left and right sides only for FS depth, with higher values on the left side. The study by Belaldavar et al. [33] evaluated FS with radiographs of Indian subjects and observed that the height and width of the right FS were greater than those of the left side in both sexes. Shireen et al. [34] used radiographs of Saudi subjects and observed that the left FS was larger than the right FS in both sexes. Likewise, Soman et al. [35], using radiographs of a sample of Indian subjects, performed a morphometric assessment of FS and found no significant differences between the right and left lengths. However, the authors observed a difference between the sides for FS width in both men and women. Tatlisumak et al. [27], who performed a study with a sample of 100 Turkish individuals using computed tomography (CT) and found that FS depth was greater on the left side. Sherif et al. [36], in turn, did not find significant differences in the measures of either side in Egyptian men or women.

The mean FS height, width, and depth obtained in this study were, respectively, 18.23 mm, 20.32 mm, and 9.78 mm for men, and 17.00 mm, 18.27 mm, and 8.01 mm for women. There were statistically significant differences between the sexes for FS the width and depth, with higher values for men ($p<0.05$). Similarly, Sherif et al. [36], using Multidetector Computed Tomography (MDCT) on a sample of 100 adult Egyptians, observed that FS depth on both sides and the left FS height were greater in men than in women. The values found were 8.76 mm for the right depth in men and 6.90 mm in women, 9.32 mm for left depth in men and 7.24 mm in women, and 13.52 mm for left height in men and 10.90 mm in women. The authors believe that FS can be used as an auxiliary method for sex estimation.

Akhlaghi et al. [37] observed, in CT images of 200 Persian individuals, a statistically significant difference between the sexes for FS height and width, with higher values for men. The left FS height showed the highest precision for sex differentiation (61.3%). Uthman et al. [16] used spiral CT images of FS in an Iraqi sample and found statistically significant differences between the sexes in the linear measures analyzed, with higher values for men.

Belaldavar et al. [33], Shireen et al. [34] and Camargo et al. [38] used radiographs to verify sexual dimorphism with FS measurements. The results of the study by Belaldavar et al. [33] showed a strong indication of differences between the sexes for FS height and width, with higher values for men. Camargo et al. [38] showed strong evidence of differences between the means of men and women for all variables studied (FS height and width on both sides), and the measurements of men were higher than those of women. Similarly, the study by Shireen et al. [34] observed significant differences between the sexes in the Saudi population, in which the mean value for all measures analyzed was higher in men than in women.

Mendonça et al. [39] evaluated the accuracy of maxillary sinuses (MS) and FS measurements in sex estimation of Brazilian adults using Multislice Computed Tomography (MCT) and found differences between the sexes. The mean height and width on both sides were significantly higher in men than in women.

However, Demiralp et al. [40] did not find significant differences between the sexes in the measurements performed (FS height, width, and depth) in 32 ancient skulls (found in excavations in Anatolia, Turkey, of around 100 years old). These findings differ from the results obtained in this study and other authors who found significant differences between the sexes when studying samples from modern populations.

Regarding age groups, this study found that all measurements were significantly higher in 18 years or older than from 6 to 11 years old. Height and depth were also significantly higher in 18 years or older than from 12 to 17 years old ($p<0.05$). Other authors performed studies with different populations and observed significant differences between ages. However, it is impossible to establish comparative parameters with our results because the age groups are diverse, as most authors used samples in the age group of 18 years or older. Akhlaghi et al. [37] divided a sample of Persian individuals into three age groups: from 20 to 34 years, 35 to 49 years, and 50 years or older. They evaluated the parameters of FS in CT images. In the age group analysis, the height and depth of the left sinus in subjects aged 20 to 34 years were significantly higher than the parameters measured in the range of 35 to 49 years old. The depth of the right sinus in subjects aged 20 to 34 years was greater than in subjects aged 50 years or older. According to the authors, with advancing age, the left FS height and depth decreased significantly. Shireen et al. [34] analyzed posteroanterior radiographs of subjects between 14 and 70 years old and found a significant morphological difference of FS relative to age in the Saudi population. Soman et al. [35] measured FS length and width in posteroanterior radiographs of Saudi subjects. They divided the sample into four age groups: 14-20 years, 21-30 years, 31-45 years, and 45 years or older. According to the authors, FS length and width on both sides increased with age in both sexes, except in men aged 45 years or older, whose values decreased.

There were no significant differences between black and white subjects and individuals with normal or above-normal BMI in any of the measures analyzed ($p>0.05$). The data available did not allow demonstrating a relationship between such variables and the factors measured.

However, further studies are required because, so far, there is no data in the literature that confront FS with the influence of skin color and nutritional status (BMI), which made it impossible to establish comparison parameters.

There are few studies analyzing CBCT images, especially in the Brazilian population. The estimates presented for each measure based on sex and age group can be used as a reference when sex or age estimation of Brazilian individuals are required.

ETHICAL APPROVAL

This study was approved by the Research Ethics Committee of the School of Dentistry of Araraquara, São Paulo State University (Unesp).

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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4 DISCUSSÃO

O presente estudo verificou se há diferenças entre os lados esquerdo e direito dos seios paranasais (seio frontal, seio maxilar e seio esfenoidal), e se há correlação das medidas lineares e volumétricas com sexo, idade, cor da pele e estado nutricional. Os seios paranasais são considerados cavidades pneumáticas por serem constituídos de ar e revestidos por mucoperiósteo recoberto por epitélio pseudoestratificado cilíndrico ciliado, no qual estabelecem conexões diretas ou indiretas com o sistema respiratório[23]. Pela especificidade de seus contornos, são considerados úteis para a identificação humana, pois fornecem informações e reduzem o risco de erros do profissional forense durante as investigações[12,13,24]. Em vários estudos, radiografias extrabucais[25-27] e tomografias computadorizadas[26,28-30] têm sido usadas para avaliar os seios da face para identificação de pessoas[13,28-30].

Diante disso, a análise radiográfica dos seios frontal, maxilar e esfenoidal é uma ferramenta útil para identificar humanos e estimar sexo, idade e ancestralidade, pois geralmente fornece um alto nível de precisão. Combinadas com a análise 2D dos seios, as imagens 3D têm implicações importantes para a identificação humana. Embora a análise 3D ainda não seja rotineira, seu uso nas Ciências Forenses é certamente um excelente meio que as novas tecnologias oferecem (Publicação 1).

A análise radiográfica do seio frontal é uma ferramenta útil para a identificação humana, pois geralmente fornece um alto grau de precisão. Juntamente com a análise bidimensional dos seios frontais, as imagens 3D são de grande valia para a identificação humana. Como esses exames (como telerradiografias frontais e tomografias computadorizadas de feixe cônico - TCFC) podem fazer parte dos registros ortodônticos, é importante que os ortodontistas conheçam essa possibilidade, estejam cientes da sua importância para as Ciências Forenses, e mantenham adequadamente os prontuários de seus pacientes (Publicação 2).

O Technical Error Measurement (TEM), em antropometria, é a forma mais comum de expressar a margem de erro; representa um indicador de acurácia e caracteriza a dimensão do controle de qualidade da medição[31,32].

Os resultados de TEM e rTEM obtidos neste estudo, tanto para área como para volume, intra e inter observador, demonstram a confiabilidade dos dados. Para todas as análises, os valores de R foram bem próximos de um, indicando excelente precisão e reprodutibilidade das medições, mostrando a confiabilidade das mesmas (Publicações 3-7).

Não encontramos diferença significativa entre os lados esquerdo e direito, tanto para área como para volume do seio maxilar. Nos estudos de Sahlstrand-Johnson et al.[33], Aktuna Belgin et al.[34], Farias Gomes et al.[35], Gulec et al.[36], Waluyo et al.[37] e Teixeira et al.[38] utilizando outras populações, também não encontraram diferença estatisticamente significativa entre o volume do seio direito e esquerdo, se assemelhando ao nosso estudo. Todavia, Bangi et al.[39], encontraram diferenças estatisticamente significantes em relação ao sexo, e entre os lados direito e esquerdo numa amostra indiana. Os autores observaram dimensões maiores no sexo masculino e no lado direito. Não observamos diferenças estatísticas significativas entre os sexos, o que é semelhante aos estudos de Saccucci et al.[40] e de Gulec et al.[36]. Porém, outros estudos, realizados com diferentes populações, obtiveram valores estatisticamente diferentes entre os sexos[33-35,38,39,41-44], diferindo deste trabalho (Publicação 3).

Tanto a área como o volume do seio maxilar foram significativamente menores na faixa de idade de 6 a 11 anos dos que nas outras duas faixas. Rani et al.[43] e Aktuna Belgin et al.[34] encontraram diferenças significativas, mas como os autores não analisaram dados de indivíduos entre 06 e 17 anos, não é possível comparar os seus achados com os nossos. Por outro lado, Sahlstrand-Johnson et al.[33], estudando apenas adultos (idades entre 18 e 65 anos), não encontraram diferenças significativas nas idades. Neste estudo para a cor de pele observa-se que tanto a área como o volume do seio foram significativamente maiores nos participantes brancos, quando comparados com os indivíduos pretos. Porém, não houve diferença significativa entre as categorias de IMC (normal ou acima do normal) quanto à área e ao volume do seio (Publicação 3).

Houve diferença significativa entre o lado esquerdo e direito para as medidas de altura e largura do seio maxilar, com exceção da profundidade, diferindo-se dos trabalhos de Bangi et al.[39], Urooge & Patil[42], Faria Gomes et al.[35], Waluyo et al.[37] e Teixeira et al.[38], que não observaram diferenças estatisticamente significativas entre os lados. Verificamos que a largura do seio maxilar foi maior em indivíduos do sexo masculino, apontando para possibilidade de uso desta medida na análise de dimorfismo sexual, o que se assemelha a alguns estudos que mostraram que dentre os parâmetros avaliados, a altura do seio foi a melhor variável discriminante para o dimorfismo sexual[38,45-47]. Da mesma forma, Faria Gomes et al.[35] afirmaram que a altura é a medida mais dimórfica, com melhor potencial para estimar o sexo. Por outro lado, Vidya et al.[48], Ahmed et al.[49], Azhar et al.[50] e Urooge & Patil[42] mostraram que a largura do seio maxilar esquerdo foi o parâmetro de discriminação, que poderia ser usado para estudar o dimorfismo sexual. Vários estudos, realizados com diferentes populações, obtiveram valores de medidas lineares do seio maxilar mais elevados para o sexo masculino, em comparação com o sexo feminino[35,38,43,45,51-,54], o que está de acordo com o presente estudo. De maneira diferente, o estudo de Najem et al.[55], analisando as mesmas medidas e realizado com uma amostra composta por 82 sujeitos egípcios, não encontrou diferenças entre os sexos (Publicação 4).

Em relação às faixas etárias, a partir dos 18 anos, a altura do seio maxilar foi significativamente maior do que na faixa etária de 12 a 17 anos. Também a partir de 18 anos, a altura e profundidade foram significativamente maiores do que na faixa de 6 a 11 anos. A faixa a partir de 18 anos apresentou medidas significativamente menores que as outras faixas para largura. No estudo de Teixeira et al.[38] (faixas etárias: 18–40 anos e >40 anos) com exceção da distância inter-sinusal, todas as medidas foram maiores no grupo mais jovem (18–40 anos), sendo este parâmetro o melhor discriminador individual. De acordo com Rani et al.[43] (faixas etárias: 21 a 73 anos) as variáveis (largura, profundidade e altura) apresentaram diferença significativa, sendo que todas diminuíram com a idade.

Por outro lado, Najem et al.[55] (faixas etárias: ≤40 e >40 anos), tendo mensurado também altura, largura e comprimento do seio maxilar, bilateralmente, e não encontraram diferenças significativas entre as idades. Porém, não foi possível estabelecer parâmetros comparativos com os nossos achados em relação aos estudos citados porque, além de as faixas etárias dos autores serem diferentes das empregadas no presente estudo, os autores não utilizaram amostras de indivíduos abaixo de 18 anos de idade. Neste estudo, os indivíduos brancos apresentaram valores maiores do que os pretos, assim como os de IMC normal apresentaram valores maiores do que os de IMC acima do normal, mas de acordo com as análises, estas medidas não apresentaram diferenças significativas (Publicação 4).

Não encontramos diferença significativa entre os lados esquerdo e direito, tanto para área como para volume do seio esfenoidal, que se assemelha aos estudos de Emirzeoglu et al.[56] e Nejaim et al.[57]. Porém, Emirzeoglu et al.[56] não mensuraram o volume por meio de reconstrução 3D de imagens tomográficas, mas utilizaram medidas bidimensionais, do plano coronal, e partir das quais foram realizadas estimativas de volume, o que difere da metodologia empregada neste estudo. Diferentemente, Oliveira et al.[58] analisando e avaliando a variação da anatomia e do volume do seio esfenoidal usando TC helicoidal encontraram diferenças nos volumes dos seios nos lados direito e esquerdo. Não observamos diferenças estatísticas significativas entre os sexos, o que se iguala aos estudos de Nejaim et al.[57], Oliveira et al.[58] e Cappella et al.[59] em que os autores verificaram que o sexo não teve influência significativa no volume do seio. Mas, outros estudos realizados com diferentes populações, obtiveram valores estatisticamente diferentes entre os sexos, o que difere deste estudo[56,60-66], sendo maiores nos homens. Em relação ao estudo de Oliveira et al.[60] os autores avaliaram a precisão das medidas de volume e também da área do seio esfenoidal e a possibilidade de dimorfismo sexual. Os autores notaram que os homens apresentaram uma média significativamente maior do que as mulheres, bem como uma variação maior tanto no volume como na área (Publicação 5).

A faixa etária a partir de 18 anos apresentou valores significativamente maiores de áreas e volumes do SE do que as outras faixas etárias. Emirzeoglu et al.[56] estimaram o volume dos seios esfenoidais, por meio de imagens de TC e avaliaram também o efeito do envelhecimento sobre o tamanho dos mesmos (faixa etária: 18 e 72 anos). Segundo os autores, foi observada correlação negativa entre o volume total dos seios e a idade (r=−0,238; p<0,05) o que significa que o tamanho dos seios tende a diminuir com a idade. Não é possível estabelecer parâmetros comparativos com o presente estudo, pois os autores não analisaram imagens de sujeitos com menos de 18 anos de idade. No estudo feito por Jat et al.[67], ao dividiram os indivíduos em diferentes faixas etárias nos intervalos de 1, 2, 3 e 4 anos, observou-se que quando estimada no intervalo de um 1 ano, a medida volumétrica foi significativa em apenas algumas faixas etárias, mas, no intervalo de 2 anos observou-se diferença significativa na maioria das faixas etárias. No intervalo de 4 anos a medida volumétrica do seio esfenoidal foi significativa em todas as faixas etárias. Os volumes médios para a população rural foram maiores que os da população urbana, assim como o volume médio foi maior nos não vegetarianos do que nos vegetarianos. No estudo de Cohen et al.[62] (faixas etárias: abaixo 65 anos e acima 65 anos) os indivíduos mais jovens apresentaram volumes significativamente maiores quando comparados com os indivíduos mais velhos. Já Oliveira et al.[58] e Koç[64] não foi encontrada correlação significativa entre idade e volume dos seios. Não houve diferença significativa entre pretos e brancos quanto à área e ao volume do seio. No entanto, neste estudo para o estado nutricional observa-se que tanto a área como o volume do seio esfenoidal foram significativamente maiores nos participantes com IMC normal, quando comparados com os indivíduos de IMC acima do normal (Publicação 5).

Neste estudo não encontramos diferença significativa entre os lados esquerdo e direito para nenhuma das medidas lineares do seio esfenoidal, o que se assemelha ao estudo de Wu et al.[68]. Por outro lado, Sherif et al.[69], não observaram diferença significativa entre os dois lados no sexo feminino, mas foi observada diferença significativa entre os lados na distância horizontal da parede anterior do SE ao ponto mais baixo da sela e na profundidade no sexo masculino, com maior valor no lado direito. Kaplanoglu et al.[70] e Kajoak et al.[71] também encontraram diferenças entre os lados. Neste estudo, a altura do SE foi significativamente maior nos homens, porém os demais parâmetros não apresentaram diferenças significativas entre os sexos. Demiralp et al.[63] e Kaplanoglu et al.[70] também encontraram diferenças entre os sexos, mostraram-se medidas maiores nos homens do que nas mulheres. Em contrapartida, Ramos et al.[65] avaliaram por meio de TCFC a possibilidade de estimativa do sexo em uma população brasileira por meio de medidas de SE, e os resultados deste estudo sugeriram que não houve diferenças estatísticas nas medidas significativas entre os sexos (Publicação 6).

Neste estudo só não houve diferença significativa entre as faixas de idade para a altura do seio esfenoidal. A partir de 18 anos, a largura e profundidade do seio foram significativamente maiores do que na faixa de 6 a 11 anos. Sob outra perspectiva, Demiralp et al.[63] não encontraram diferenças significativas na altura, largura e na distância da parede ântero-posterior do seio em relação às idades. Há uma escassez de trabalhos na literatura quando se considera o dimorfismo sexual e a idade por meio das medidas lineares do seio esfenoidal. Assim, os resultados descritos neste estudo podem ser o ponto de princípio para pesquisas e avaliações futuras neste campo em relação às medidas lineares deste seio. Em relação à cor de pele (brancos e pretos) e ao IMC (normal ou acima do normal), não encontramos diferenças significativas em nenhuma das medidas do seio esfenoidal (Publicação 6).

Neste estudo encontramos assimetria estatisticamente significativa entre os lados esquerdo e direito apenas para profundidade do seio frontal, sendo o lado esquerdo maior, o que está de acordo com Tatlisumak et al.[72] que também verificaram que a profundidade do seio frontal foi maior no lado esquerdo. Shireen et al.[73] utilizaram radiografias de sujeitos sauditas e também observaram que lado esquerdo foi maior que o lado direito, em ambos os sexos.

Da mesma forma, Soman et al.[74], utilizando radiografias de uma amostra de sujeitos indianos, realizaram uma avaliação morfométrica do seio frontal e observaram diferença entre os lados na largura do seio, em homens e mulheres. No estudo de Belaldavar et al.[75], avaliando o seio frontal por meio de radiografias em indianos, observaram que a altura e a largura do direito foram maiores que a do lado esquerdo em ambos os sexos. Por outro lado, Sherif et al.[69] não encontraram diferenças significativas nas medidas de ambos os lados em homens ou mulheres egípcios (Publicação 7).

Observamos diferenças estatísticas significativas entre os sexos para largura e profundidade do seio frontal, sendo maiores no sexo masculino. Sherif et al.[69] observaram que profundidade do seio, em ambos os lados, e a altura do esquerdo foi maior no sexo masculino do que no sexo feminino. Uthman et al.[30] observaram que as medidas lineares analisadas mostraram diferenças estatisticamente significativas entre os sexos, com valores maiores nos homens. Akhlaghi et al.[76] observaram que a altura e a largura do seio frontal tiveram uma diferença estatisticamente significativa entre os sexos, sendo os valores maiores nos homens. A maior precisão para a diferenciação entre os sexos foi apresentada pela altura do seio frontal esquerdo (61,3%). Camargo et al.[77], Belaldavar et al.[75] e Shireen et al.[73] utilizaram radiografias para verificar o dimorfismo sexual por meio de medidas do seio frontal e observaram forte indicação de diferenças entre os sexos com valores maiores no sexo masculino. Mendonça et al.[54] avaliaram a acurácia das medidas do seio maxilar e do seio frontal na estimativa de sexo em adultos brasileiros utilizando Tomografia Computadorizada Multislice (TCM), e também encontraram diferenças entre os sexos. As médias da altura e da largura, em ambos os lados, foram significativamente maiores no sexo masculino, em relação ao feminino. Por outro lado, Demiralp et al.[63], não encontraram diferenças significativas entre os sexos nas medidas realizadas (altura, largura e profundidade do seio frontal (Publicação 7).

Em relação às faixas etárias, neste estudo verificamos que a partir de 18 anos todas as medidas foram significativamente maiores do que na faixa de 6 a 11 anos, assim como a altura e a profundidade foram significativamente maiores do que na faixa de 12 a 17 anos. Outros estudos utilizaram diferentes populações e foi observado diferenças significativas entre as idades. Porém, não há como estabelecer parâmetros comparativos com os nossos resultados, pois as faixas etárias são diversas; a maior parte dos autores utilizou amostras a partir de 18 anos. Segundo Akhlaghi et al.[76] (faixas etárias: de 20 a 34 anos, de 35 a 49 anos e a partir de 50 anos) nas análises por faixa etária, a altura e a profundidade do seio esquerdo nos sujeitos de 20 a 34 anos foram significativamente maiores do que os parâmetros medidos na faixa de 35 a 49 anos. A profundidade do seio direito nos indivíduos de 20 a 34 anos foi maior do que nos sujeitos com idades a partir de 50 anos. Segundo os autores, com o avançar da idade, a altura do seio frontal do lado esquerdo e a profundidade diminuíram significativamente. Shireen et al.[73] (faixa etária: entre 14 e 70 anos) verificaram diferença morfológica significativa do seio frontal em relação à idade na população saudita.

Soman et al.[74] (faixas etárias: 14-20 anos, 21-30 anos, 31-45 anos e a partir de 45 anos) observaram que o comprimento e a largura do seio frontal de ambos os lados aumentaram com a idade em ambos os sexos, exceto em homens a partir de 45 anos, onde diminuiu. Não observamos diferenças significativas entre sujeitos pretos e brancos e entre indivíduos com IMC normal ou acima do normal em nenhuma das medidas analisadas (Publicação 7).

Até o momento não encontramos na literatura estudos que relacionem medidas lineares dos seios maxilar, frontal e esfenoidal e medidas volumétricas dos seios maxilar e esfenoidal com cor da pele e IMC, o que não nos permitiu estabelecer parâmetros comparativos (Publicações 3-7).

Os resultados encontrados neste estudo permitem algumas importantes considerações para análises lineares e volumétricas dos seios paranasais, pois as variáveis em que foram observadas diferenças significativas nas medidas podem auxiliar em análises de dimorfismo sexual, estimativa da idade, estado nutricional e cor de pele de brasileiros, contribuindo com as Ciências Forenses, particularmente com a Antropologia Forense, em trabalhos de identificação humana, auxiliando a Justiça e a sociedade. Em contrapartida, para as variáveis em que não foram observadas diferenças significativas, ficou evidenciado que não se conseguiu, através dos dados disponíveis, demonstrar a existência de relação entre as variáveis analisadas. Além disso, diferenças entre populações têm sido relatadas na literatura[78], o que demonstra a necessidade de dados populacionais específicos. Estudos adicionais são necessários devido à escassez de investigações sobre tais parâmetros.

5 CONCLUSÃO

De acordo com as publicações do presente estudo, pode-se concluir que:

Publicação 1: A análise imaginológica dos seios paranasais frontal, maxilar e esfenoidal é uma ferramenta útil para a identificação humana, bem como na estimativa do sexo, idade e ancestralidade, pois comumente fornece um alto nível de exatidão. Em conjunto com a análise bidimensional dos seios, as imagens tridimensionais são de grande relevância para a identificação humana. Embora a análise tridimensional ainda não seja rotineira, seu uso nas Ciências Forenses é, sem dúvida, um excelente meio proporcionado pelas novas tecnologias.

Publicação 2: Em Ciências Forenses, a utilização da análise radiográfica do seio frontal é ferramenta relevante para a identificação humana, pois em geral fornece um alto grau de precisão. Neste contexto, juntamente com as análises bidimensionais, as imagens 3D do seio frontal são de grande valor. Portanto, é importante que os ortodontistas conheçam essa possibilidade, estejam cientes da importância dos exames de imagem para as Ciências Forenses e mantenham adequadamente os prontuários de seus pacientes.

Publicação 3: Não foram apresentadas diferenças estatísticas significativas entre os lados esquerdo e direito, assim como em relação aos sexos, o que não nos permite recomendar para a análise de dimorfismo sexual o emprego de medidas de volume e área de seios maxilares. O mesmo foi observado em relação ao IMC. Mas, o volume e a área do seio maxilar podem auxiliar na estimativa da idade e da cor de pele dos indivíduos.

Publicação 4: As medidas de altura e largura do SM apresentaram diferenças significativas entre os lados direito e esquerdo, e que houve variabilidade anatômica entre os sexos para a largura dos SM. Indivíduos do sexo masculino apresentaram valores de largura de SM maiores do que os do sexo feminino, o que pode auxiliar em análises de dimorfismo sexual. Todavia, as medidas de altura e profundidade não apresentaram diferença significativa entre os sexos. Foram também encontradas diferenças significativas entre as faixas etárias. Não houve diferença significativa nas medidas para cor de pele e estado nutricional.

Publicação 5: Não foram observadas diferenças estatísticas significativas entre homens e mulheres, o que não nos permite indicar a aplicação de medidas de volume e área dos SE para a verificação de dimorfismo sexual; o mesmo ocorreu em relação à cor de pele. Todavia, tais medidas podem auxiliar na estimativa da idade e no estado nutricional dos indivíduos, pois foram observadas diferenças significativas entre estes grupos.

Publicação 6: Não houve diferença significativa entre os lados dos SE nas medidas lineares, mas foi observada variabilidade anatômica entre os sexos, já que o grupo masculino apresentou valores significativamente maiores do que o feminino para a altura do seio esfenoidal. Todavia, as demais medidas não apresentaram diferença significativa entre os sexos. Foram também encontradas diferenças significativas entre as faixas etárias, mas não houve diferença significativa nas medidas para cor de pele e estado nutricional.

Publicação 7: Houve assimetria estatisticamente significativa para a profundidade do seio frontal entre os lados direito e esquerdo. Houve diferenças entre os sexos, com os homens apresentando medidas significativamente maiores na largura e profundidade do SF, e também entre as faixas etárias. Porém, não houve diferença significativa nas medidas de cor de pele e o IMC.

Os achados deste estudo foram obtidos por meio de medidas antropométricas (medidas de estruturas do corpo humano) e podem ajudar na criação de um protocolo na área de Ciências Forenses, particularmente em Antropologia Forense, ajudando no perfil biológico e eventualmente em processos de identificação humana de indivíduos brasileiros, auxiliando a Justiça e a sociedade.

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APÊNDICE A – METODOLOGIA DETALHADA

1 Material

1.1 Medidas lineares dos seios maxilar, frontal e esfenoidal

a) 238 imagens (DICOM) de tomografia computadorizada de feixe cônico
b) Computador marca Dell
Processador Intel(R) Core(TM) i5-8265U CPU @ 1.60GHz 1.80 GHz
Intel UHD Graphics 620
Placa de vídeo Nvidia GeForce MX130
RAM: 8,00GB
Sistemas operacionais: Windows 10 Pro
c) Software DDS-Pro® 2.12.0_2021 (DPP Systems, Czestochowa, Polônia)
d) Google Planilhas
a) HD Externo de 500 GB

1.1.2 Material - Medidas volumétricas do seio maxilar

a) 161 imagens (DICOM) de tomografia computadorizada de feixe cônico
b) Computador marca Dell
Processador Intel(R) Core(TM) i5-8265U CPU @ 1.60GHz 1.80 GHz
Intel UHD Graphics 620
Placa de vídeo Nvidia GeForce MX130
RAM: 8,00GB
Sistemas operacionais: Windows 10 Pro
c) Software DDS-Pro™ 2.14.2_2022 versão beta (DPP Systems, Czestochowa, Polônia)
d) Google Planilhas
a) HD Externo de 500 GB

1.1.3 Material - Medidas volumétricas do seio esfenoidal

a) 113 imagens (DICOM) de tomografia computadorizada de feixe cônico
b) Computador marca Dell
Processador Intel(R) Core(TM) i5-8265U CPU @ 1.60GHz 1.80 GHz

Intel UHD Graphics 620
Placa de vídeo Nvidia GeForce MX130
RAM: 8,00GB
Sistemas operacionais: Windows 10 Pro
c) Software DDS-Pro™ 2.14.2_2022 versão beta (DPP Systems, Czestochowa, Polônia)
d) Google Planilhas
a) HD Externo de 500 GB

2 Método

2.1 Seleção da amostra, Tipo de arquivo e Tipo de equipamento

Todas as imagens de tomografia computadorizada de feixe cônico (TCFC) foram obtidas do banco de dados de responsabilidade de um dos pesquisadores. Todavia, foi mantida em confidencialidade a identidade dos indivíduos, mantendo a privacidade dos mesmos, evitando que quaisquer dados pessoais fossem expostos. A amostra foi composta por imagens de TCFC de indivíduos brasileiros vivos dos sexos feminino e masculino, armazenadas em um HD Externo (500 GB).

Esta pesquisa foi submetida ao Comitê de Ética em Pesquisa em Seres Humanos da Faculdade de Odontologia de Araraquara – UNESP, e aprovada pelo mesmo em 10/09/2021 (CAAE - nº 47706121.4.0000.5416) (ANEXO B).

As imagens selecionadas foram disponibilizadas e utilizadas em formato DICOM (Digital Imaging and Communications in Medicine) apresentando campo de visão de tamanho máximo abrangendo toda a região de cabeça, sendo descartadas as imagens cortadas. As aquisições foram obtidas por um tomógrafo de feixe cônico i-CAT. A TCFC é um método que proporciona imagens nítidas da região da cabeça e pescoço devido ao fato de os fótons de raio-x serem usados com maior eficiência. Produz imagens de alta qualidade, permitindo que os indivíduos se mantenham sentados reduzindo a deformação dos tecidos moles. Além disso, a duração do exame é curta em comparação com a tomografia computadorizada multislice.

Para obtenção das medidas lineares foi utilizado o software DDS-Pro® 2.12.0_2021 (DPP Systems, Czestochowa, Polônia) e para as medidas volumétricas a versão beta do software DDS-Pro™ 2.14.2_2022 versão beta (DPP Systems, Czestochowa, Polônia).

2.2 Descrição das variáveis

Foram consideradas as variáveis sexo, idade, cor da pele e índice de massa corporal (IMC). Todavia, nem todas as variáveis foram consideradas para todos indivíduos, pois alguns não dispunham de todas as informações. Foi também avaliada a diferença entre os lados esquerdo e direito.

Para calcular o IMC foi aplicada a fórmula: IMC = peso/altura², os valores de referência foram estimados segundo a seguinte classificação:

- baixo peso valores < 18,5;
- peso normal com valores entre 18,5 e 24,9;
- sobrepeso com valores entre 25 e 29,9
- obesidade, com valores > 30,0.

A informação referente à cor da pele foi obtida através de imagens fotográficas presentes nos arquivos. Para este estudo os indivíduos foram classificados em brancos e não brancos segundo a cor de pele, tendo como referência a classificação do IBGE (censo demográfico - 2000)[1]. O IMC foi dividido em normal e acima do normal, e foram determinadas as faixas etárias de 06 aos 11 anos (subadultos), 12 aos 17 anos (subadultos) e a partir de 18 anos (adultos).

Os valores obtidos foram armazenados em uma tabela desenvolvida com uso de Planilhas Google, que auxiliou nas análises dos dados.

Para as medidas lineares a amostra foi composta por 238 imagens de TCFCs de indivíduos brasileiros (139 do sexo feminino e 99 do sexo masculino). Os indivíduos tinham idade entre 06 e 68 anos, sendo 182 indivíduos de cor branca e 47 de cor preta, 58 com IMC normal e 61 acima do normal.

Foram consideradas 3 faixas etárias, tendo sido estabelecidos os seguintes grupos etários: de 06 a 11 anos (n=49), 12 a 17 anos (n=69) e a partir de 18 anos (n=118) (Tabela 1).

Tabela 1 - Perfil da amostra estudada (n=238)

Variável	Categoria	Frequência (%)
Sexo	Feminino	139 (58,4%)
	Masculino	99 (41,6%)
Faixa de idade (anos)	De 6 a 11	49 (20,6%)
	De 12 a 17	69 (29,0%)
	A partir de 18	118 (49,6%)
	Sem informação	2 (0,8%)
Cor de pele	Branca	182 (76,5%)
	Preta	47 (19,5%)
	Sem informação	9 (3,8%)
IMC	Normal	58 (24,4%)
	Acima do normal	61 (25,6%)
	Sem informação	119 (50,0%)

IMC = Índice de massa corporal.

Fonte: Elaboração própria.

Em relação às medidas volumétricas do seio maxilar, a amostra foi composta por 161 TCFCs (89 f do sexo feminino e 72 do sexo masculino). Os indivíduos tinham idade entre 06 e 68 anos, sendo 120 indivíduos de cor branca e 37 de cor preta, 37 com IMC normal e 44 acima do normal. Foram estabelecidos os seguintes grupos etários: de 06 a 11 anos (n=37), 12 a 17 anos (n=52) e a partir de 18 anos (70 adultos) (Tabela 2).

Tabela 2 - Perfil da amostra estudada (n=161)

Variável	Categoria	Frequência (%)
Sexo	Feminino	89 (55,3%)
	Masculino	72 (44,7%)
Faixa de idade (anos)	De 6 a 11	37 (23,0%)
	De 12 a 17	52 (32,3%)
	A partir de 18	70 (43,5%)
	Sem informação	2 (1,2%)
Cor de pele	Branca	120 (74,5%)
	Preta	37 (23,0%)
	Sem informação	94 (2,5%)
IMC	Normal	37 (23,0%)
	Acima do normal	44 (27,3%)
	Sem informação	80 (49,7%)

IMC = Índice de massa corporal.

Fonte: Elaboração própria.

Para as medidas volumétricas do seio esfenoidal, a amostra foi composta por 113 TCs (67 do sexo feminino e 46 do sexo masculino). Os indivíduos tinham idade entre 07 e 68 anos, sendo 83 indivíduos de cor branca e 26 de cor preta, 23 com IMC normal e 35 acima do normal. Foram estabelecidos os seguintes grupos etários: de 06 a 11 anos (n=19), 12 a 17 anos (n=31) e a partir de 18 anos (62 adultos) (Tabela 3).

Tabela 3 - Perfil da amostra estudada (n=113)

Variável	Categoria	Frequência (%)
Sexo	Feminino	67 (59,3%)
	Masculino	46 (40,7%)
Faixa de idade (anos)	De 6 a 11	19 (16,1%)
	De 12 a 17	31 (27,4%)
	A partir de 18	62 (54,9%)
	Sem informação	1 (0,9%)
Cor de pele	Branca	83 (73,4%)
	Preta	26 (23,0%)
	Sem informação	4 (3,5%)
IMC	Normal	23 (20,4%)
	Acima do normal	35 (31,0%)
	Sem informação	55 (48,7%)

IMC = Índice de massa corporal

Fonte: Elaboração própria.

2.3 Treinamento dos examinadores e Medidas

Foi realizada uma ampla revisão da literatura para obtenção de informações referentes à base teórica, aplicada na abordagem do tema e na questão do estudo. Sendo assim, por meio de uma análise criteriosa da bibliografia científica publicada sobre a temática, obteve-se embasamento teórico e definida a metodologia para o desenvolvimento da parte experimental da pesquisa. Por meio disso, foram desenvolvidos mecanismos para capacitação em realizar as medidas corretamente, fornecidos por meio da estrutura conceitual. O treinamento foi realizado para calibrar os examinadores e verificar a validade das medidas, e em seguida, todas as imagens foram examinadas.

Dois examinadores foram calibrados para realizar as medidas lineares estudadas nesta pesquisa, por meio da análise de 30 imagens de TCFC, com o emprego do software DDS-Pro® 2.12.0_2021 (DPP Systems, Czestochowa, Polônia) e DDS-Pro™ 2.14.2_2022 versão beta (DPP Systems, Czestochowa, Polônia) para as medidas volumétricas.

As medidas lineares realizadas nesta pesquisa foram:

- Altura do seio maxilar
- Largura do seio maxilar
- Profundidade do seio maxilar

- Altura do seio frontal
- Largura do seio frontal
- Profundidade do seio frontal

- Altura do seio esfenoidal
- Largura do seio esfenoidal
- Profundidade do seio esfenoidal

As medidas volumétricas realizadas nesta pesquisa foram:

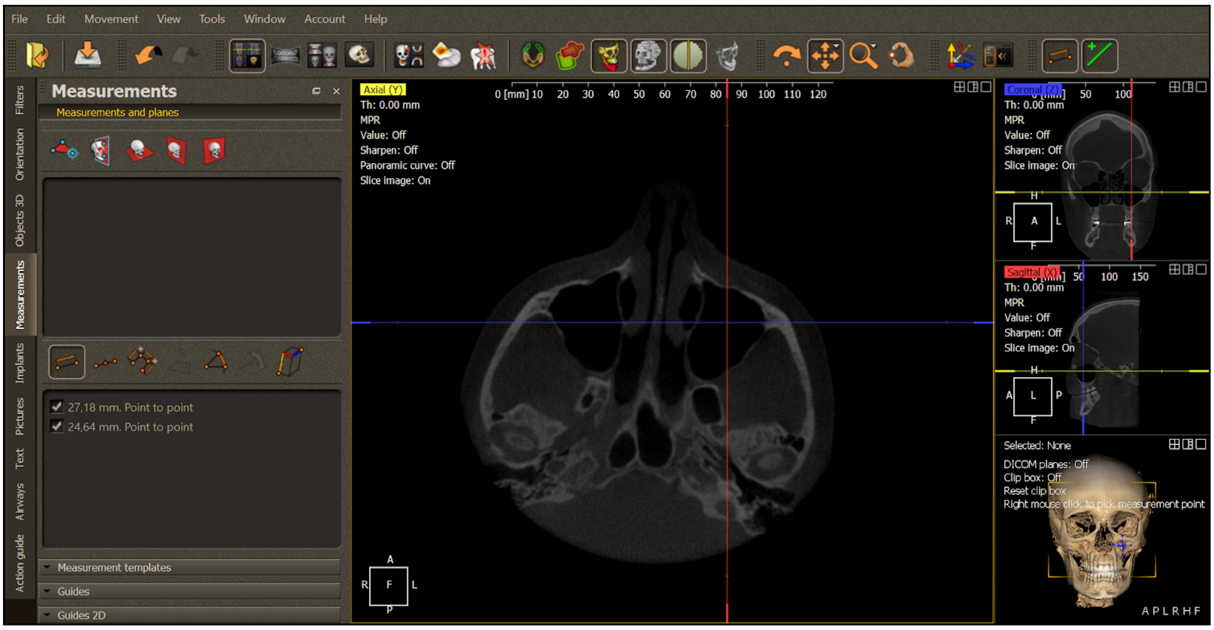
- Área do seio maxilar
- Volume do seio maxilar

- Área do seio esfenoidal
- Volume do seio esfenoidal

Ambos os lados (direito e esquerdo) foram mensurados, para todos os seios e todas as medidas, tanto bi como tridimensionais. Porém, nos casos em que um seio apresentou alguma patologia, obliterações, malformações, e/ou traumas, somente o outro foi mensurado.

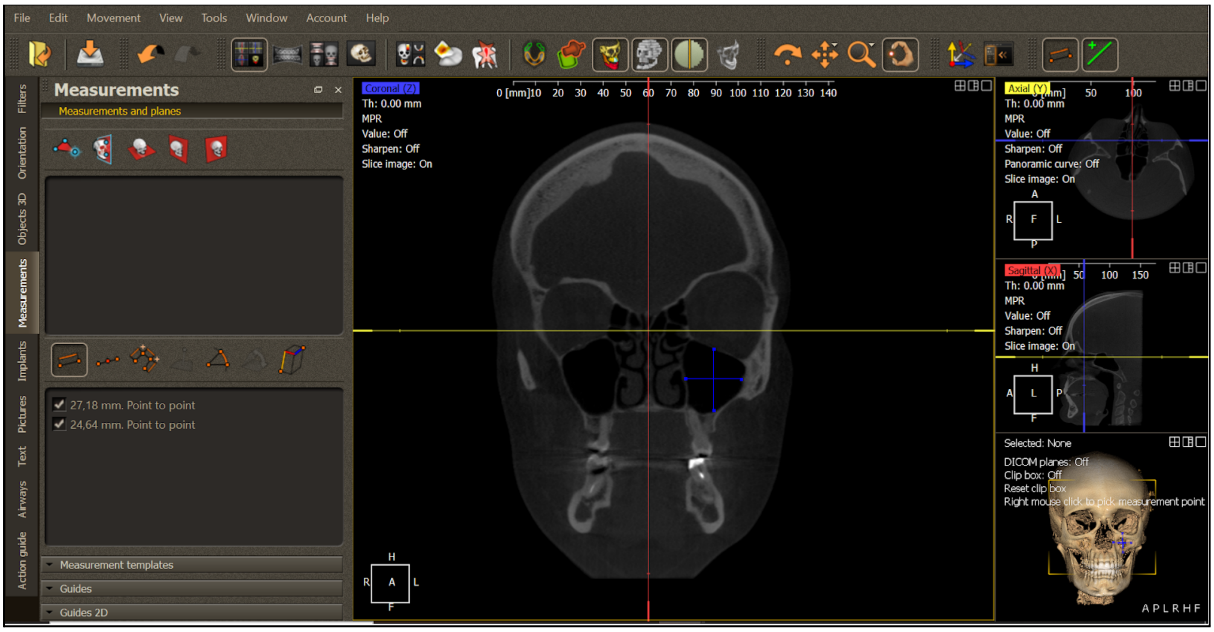
As figuras a seguir demonstram as medidas lineares dos seios maxilar, frontal e esfenoidal (Figuras 1-12).

Figura 1 - Abertura máxima do seio maxilar no corte axial para as medidas de largura e altura



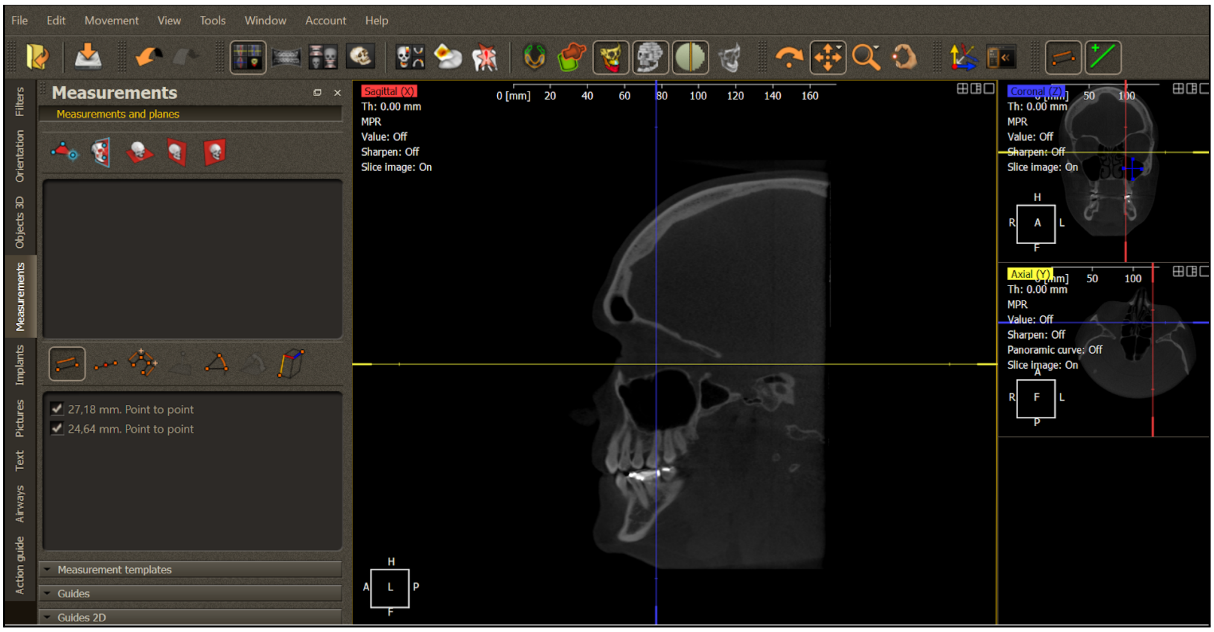
Fonte: Arquivo pessoal da autora.

Figura 2 - Medidas lineares (altura e largura) do seio maxilar no corte coronal



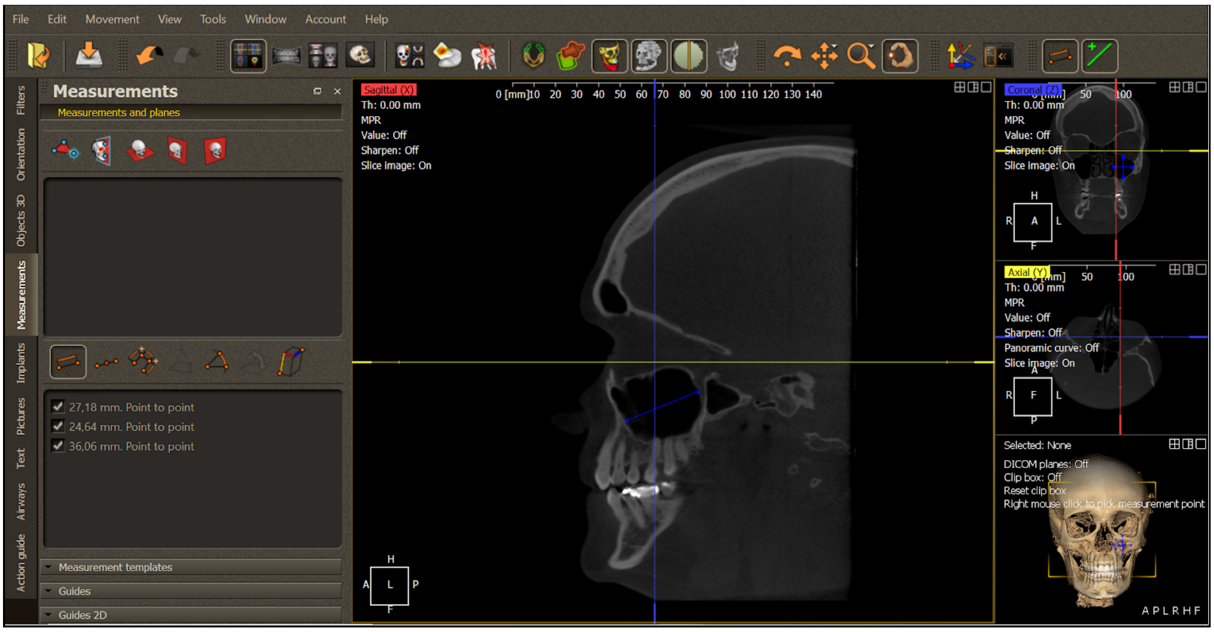
Fonte: Arquivo pessoal da autora.

Figura 3 - Abertura máxima do seio maxilar no corte sagital para a medida de profundidade



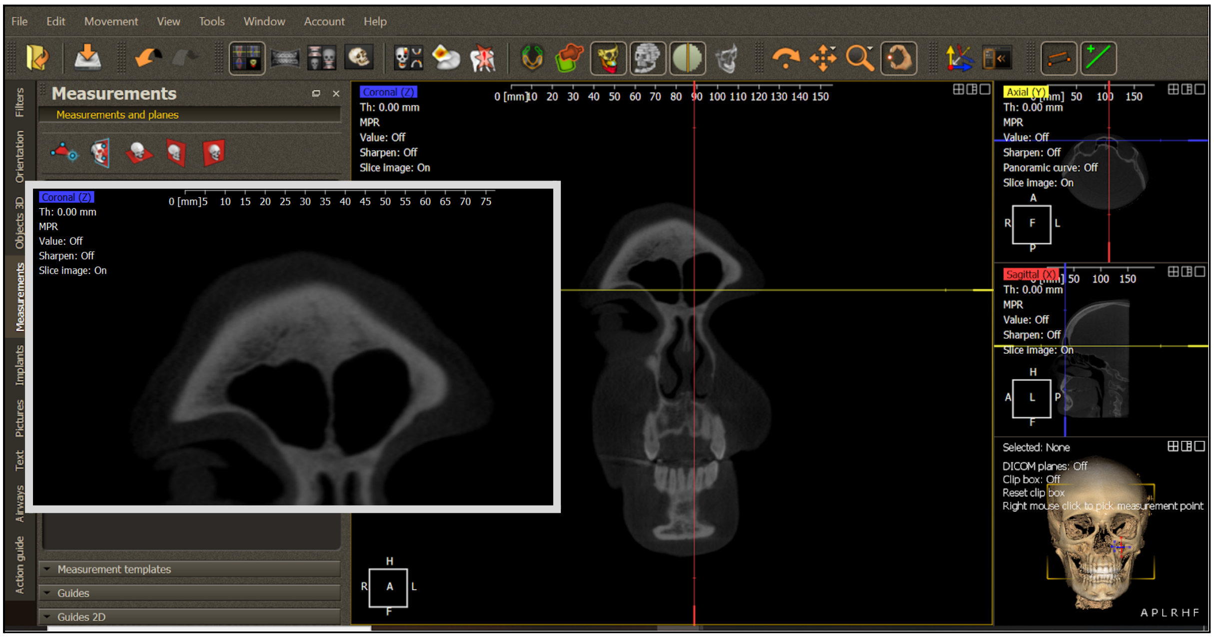
Fonte: Arquivo pessoal da autora.

Figura 4 - Medida linear (profundidade) do seio maxilar no corte sagital



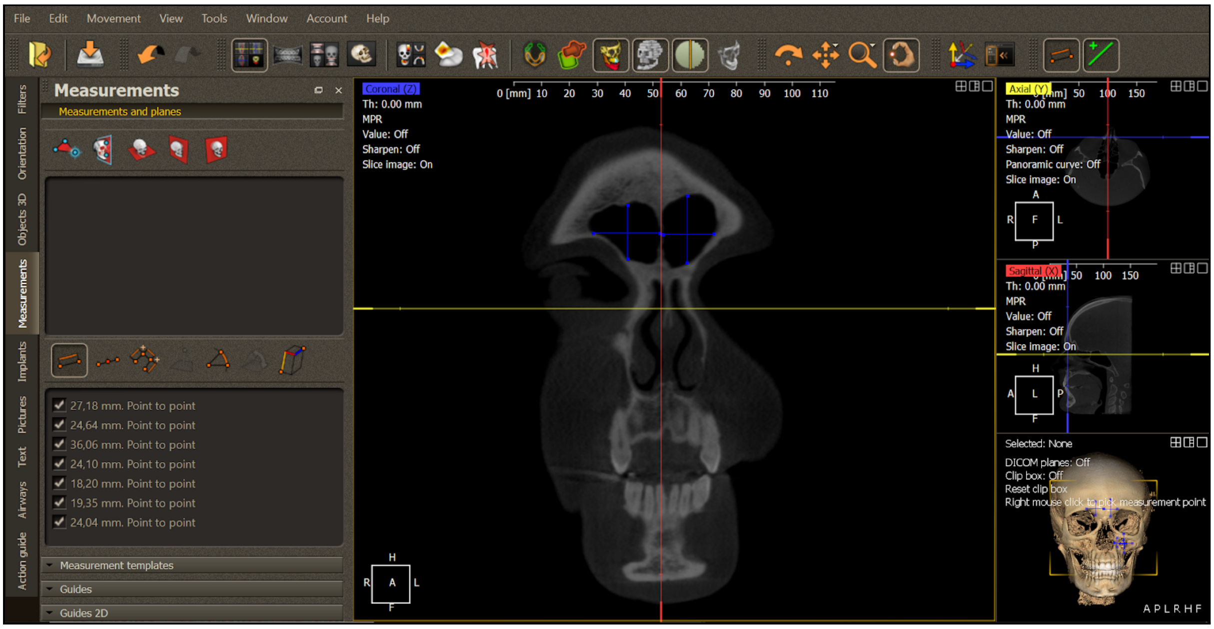
Fonte: Arquivo pessoal da autora.

Figura 5 - Abertura máxima do seio frontal no corte coronal, considerando a linha mediana que divide os lados esquerdo e direto para as medidas de altura e largura



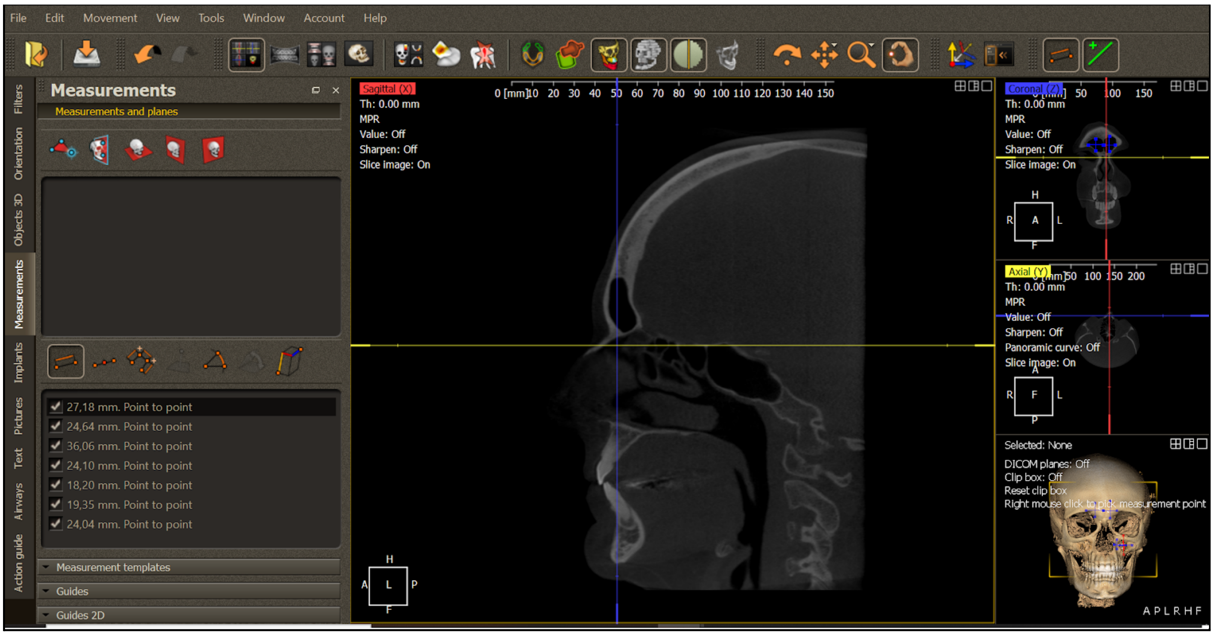
Fonte: Arquivo pessoal da autora.

Figura 6 - Medidas lineares (altura e largura) do seio frontal no corte coronal



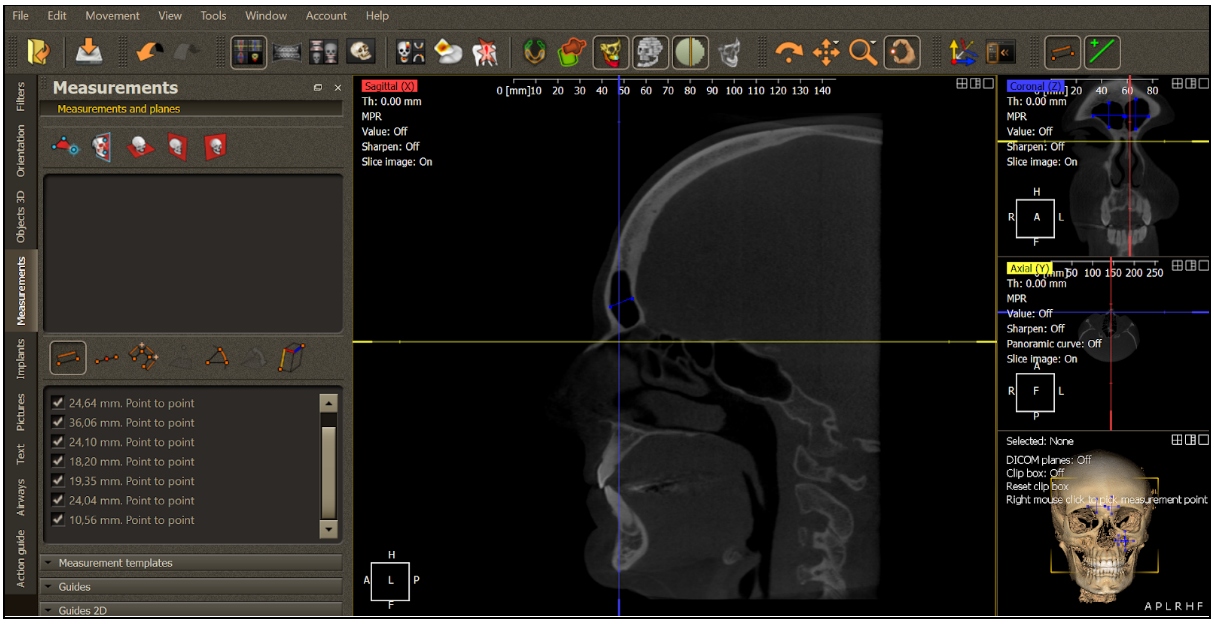
Fonte: Arquivo pessoal da autora.

Figura 7 - Abertura máxima do seio frontal no corte sagital para a medida de profundidade



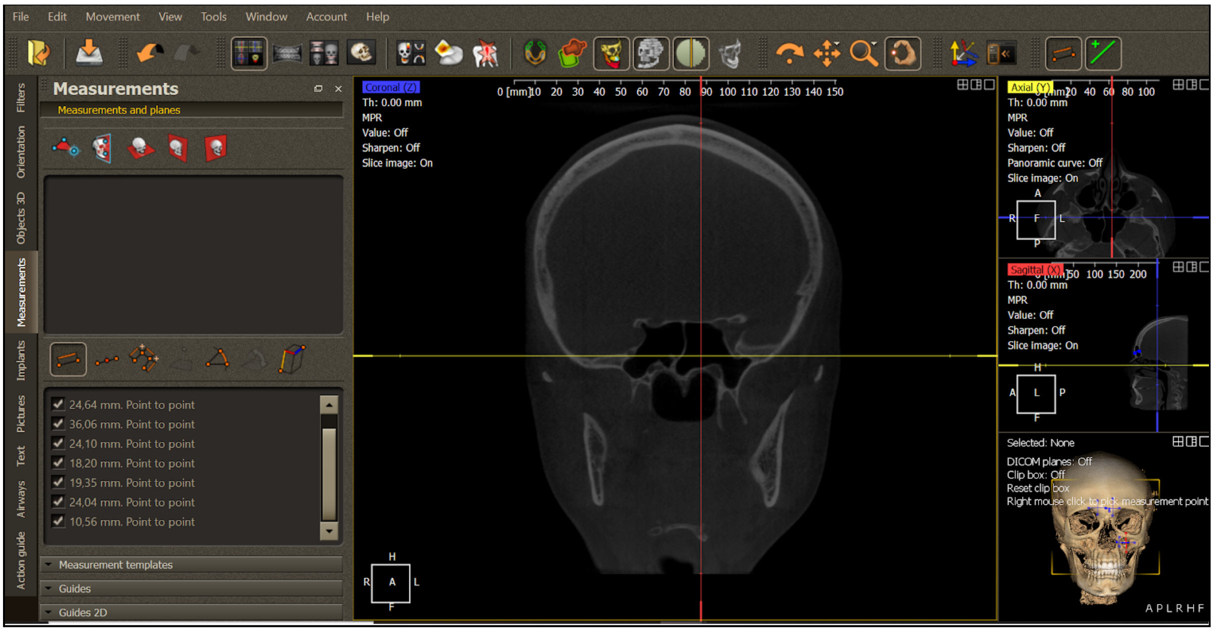
Fonte: Arquivo pessoal da autora.

Figura 8 - Medida linear (profundidade) do seio frontal no corte sagital



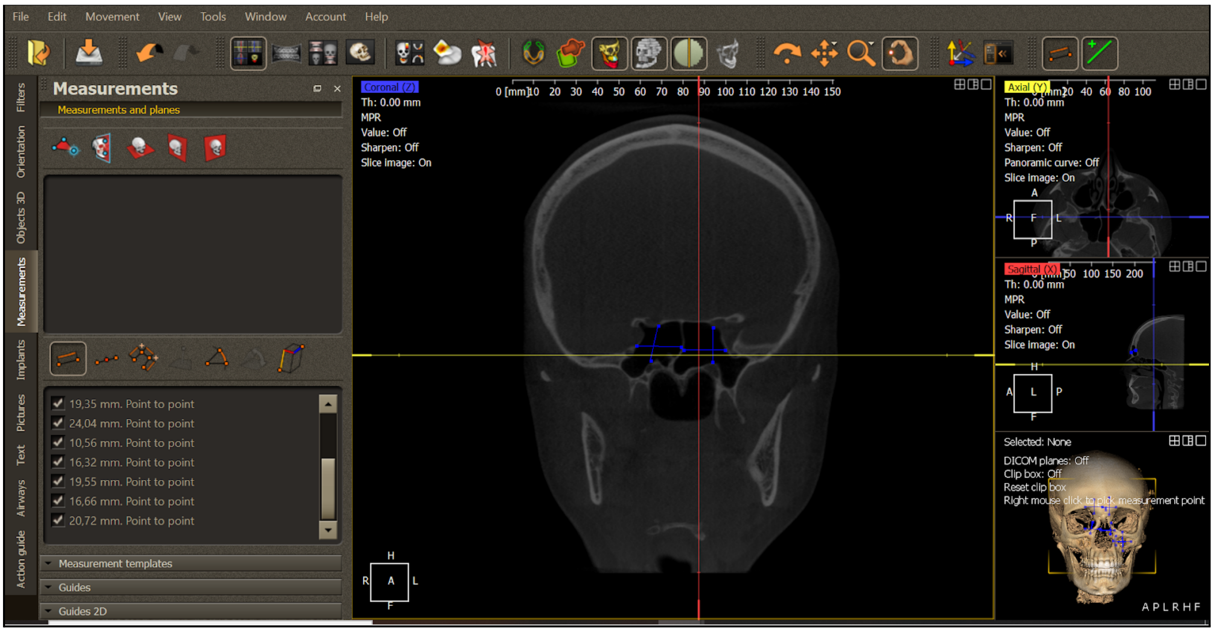
Fonte: Arquivo pessoal da autora.

Figura 9 - Abertura máxima do seio esfenoidal no corte coronal, considerando a linha mediana que divide os lados esquerdo e direto para as medidas de altura e largura



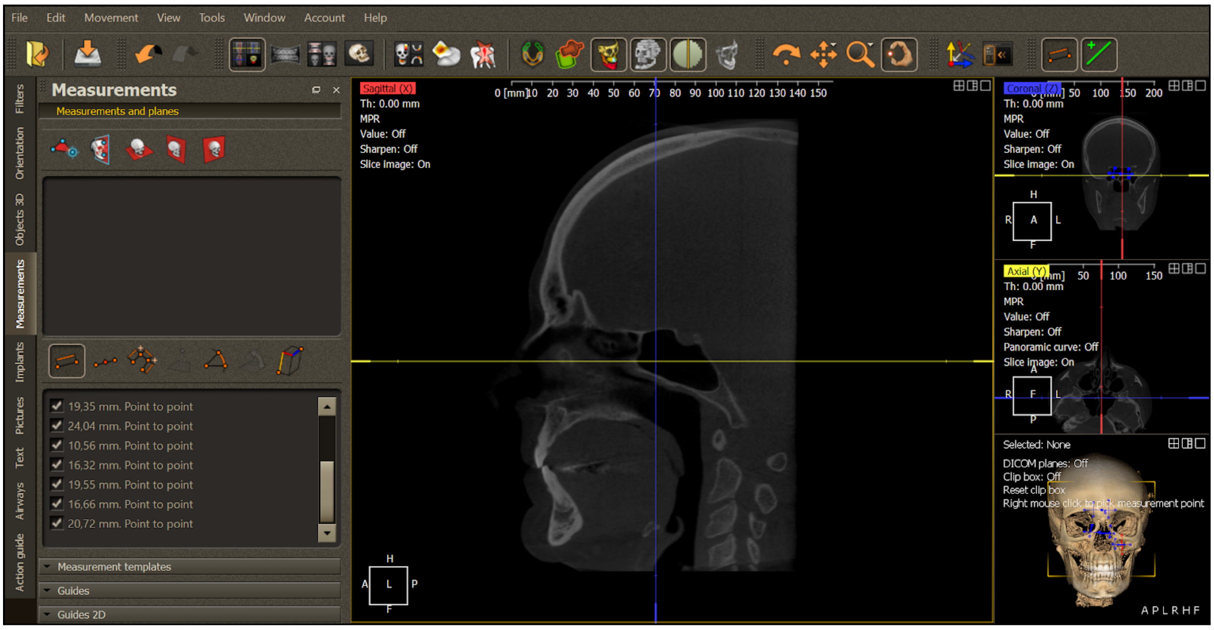
Fonte: Arquivo pessoal da autora.

Figura 10 - Medidas lineares (altura e largura) do seio esfenoidal no corte coronal



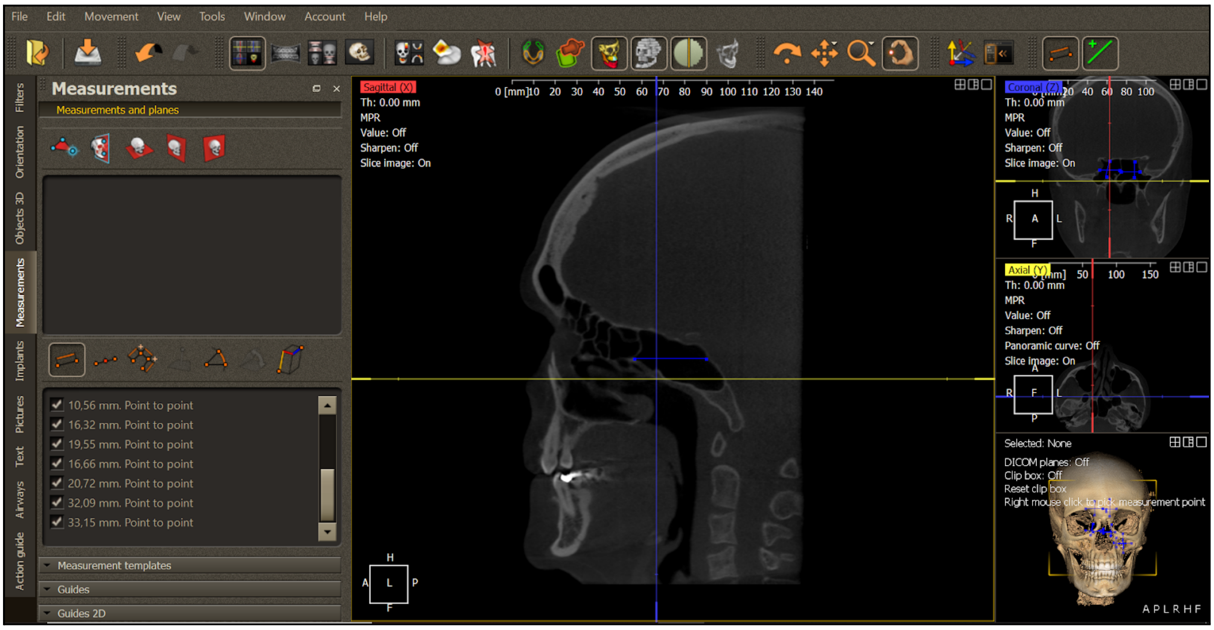
Fonte: Arquivo pessoal da autora.

Figura 11 - Abertura máxima do seio esfenoidal no corte sagital para a medida de profundidade



Fonte: Arquivo pessoal da autora.

Figura 12 - Medida linear (profundidade) do seio esfenoidal no corte sagital



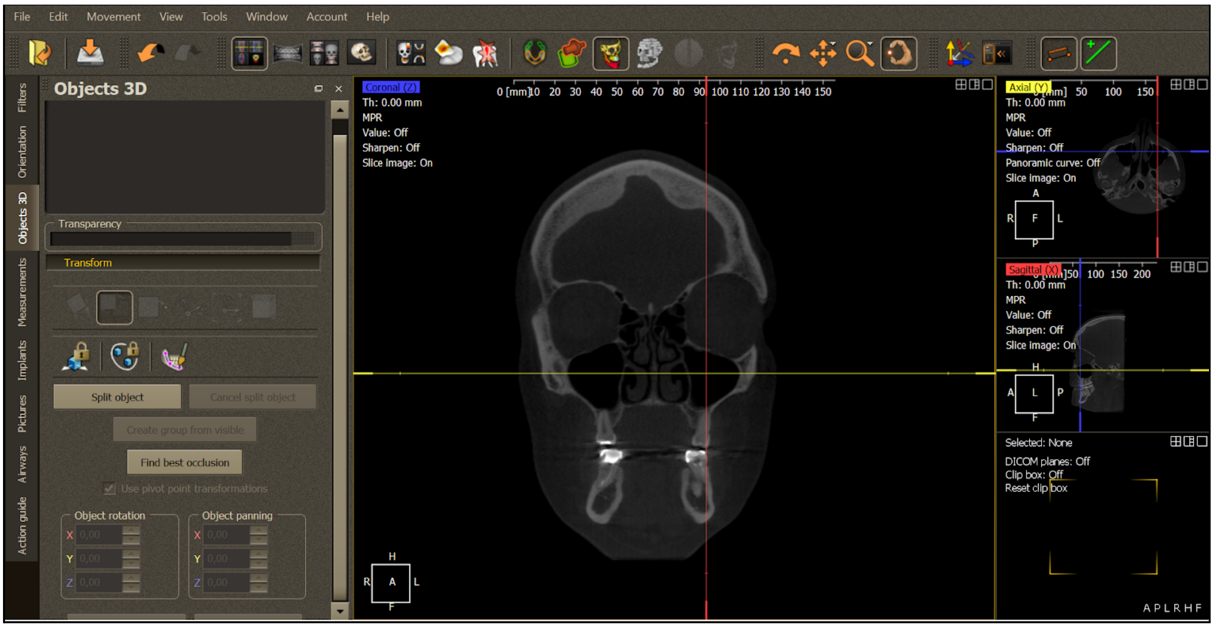
Fonte: Arquivo pessoal da autora.

Em todas as imagens, as medidas lineares de altura e largura foram feitas no corte coronal e as medidas de profundidade foram feitas no corte sagital.

Para as medidas volumétricas, na opção “Airways”, ferramenta “Point tools”, foram utilizados os seguintes parâmetros, para a delimitação dos seios maxilar e esfenoidal, nos planos sagital, axial e coronal (Figura 13-16):

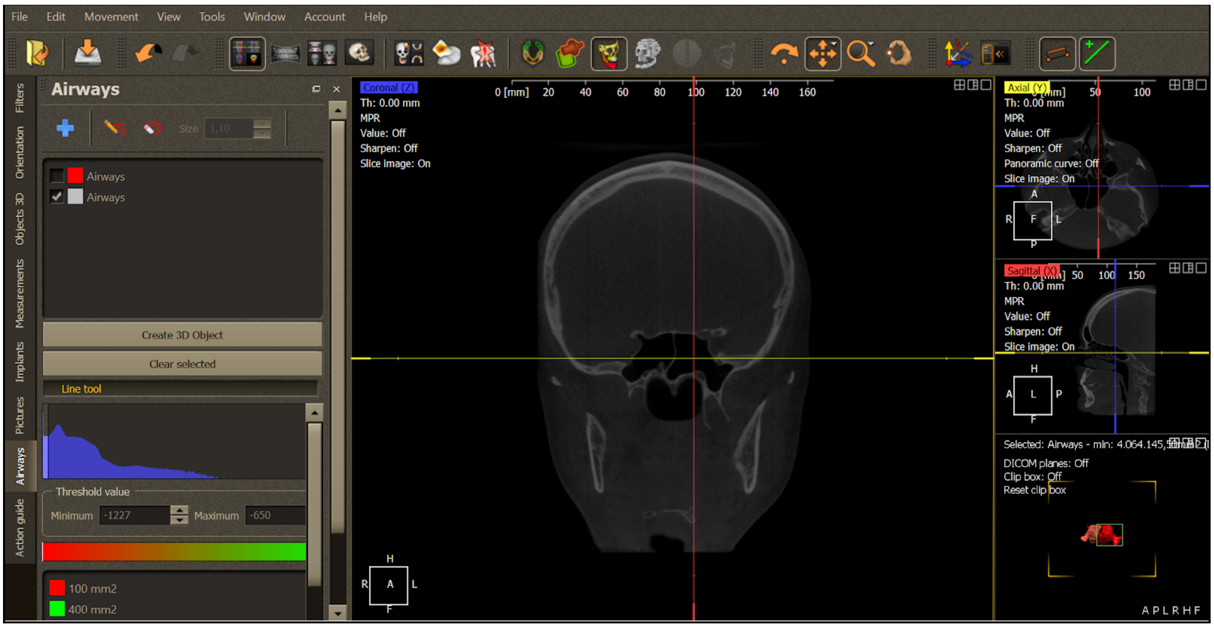
- Blocker radius: 10,00
- Difference from: -300
- Difference to: 300
- Maximal opening diameter: 2.00

Figura 13 - Abertura máxima do seio maxilar esquerdo no corte sagital para delimitação



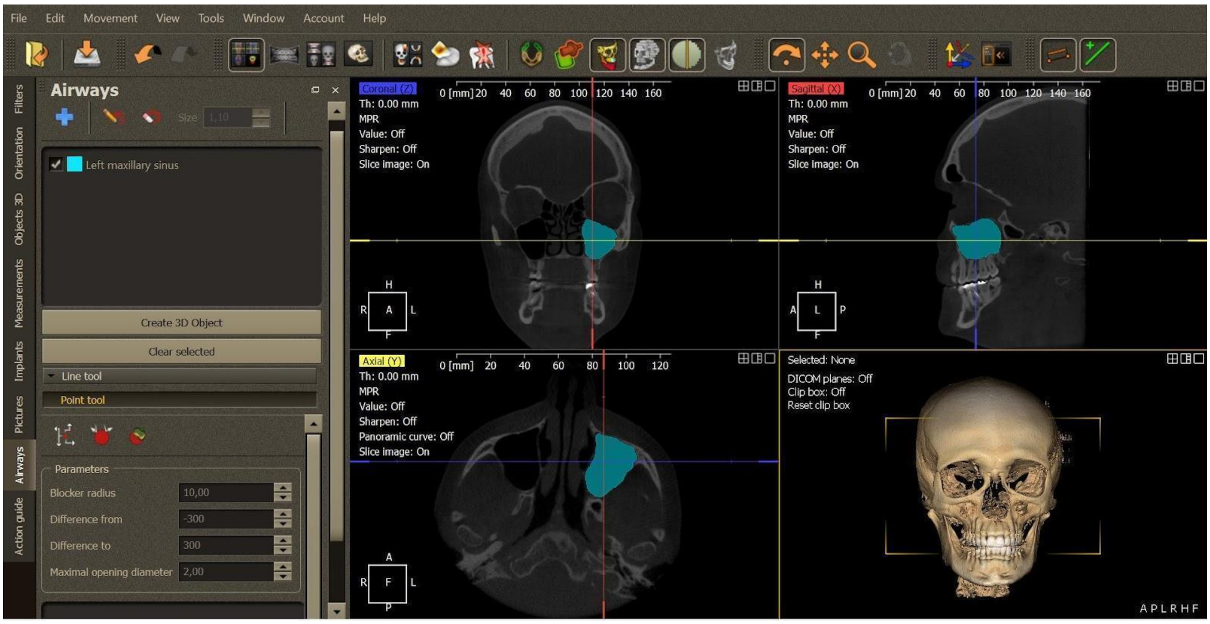
Fonte: Arquivo pessoal da autora.

Figura 14 - Abertura máxima do seio esfenoidal esquerdo no corte sagital para delimitação



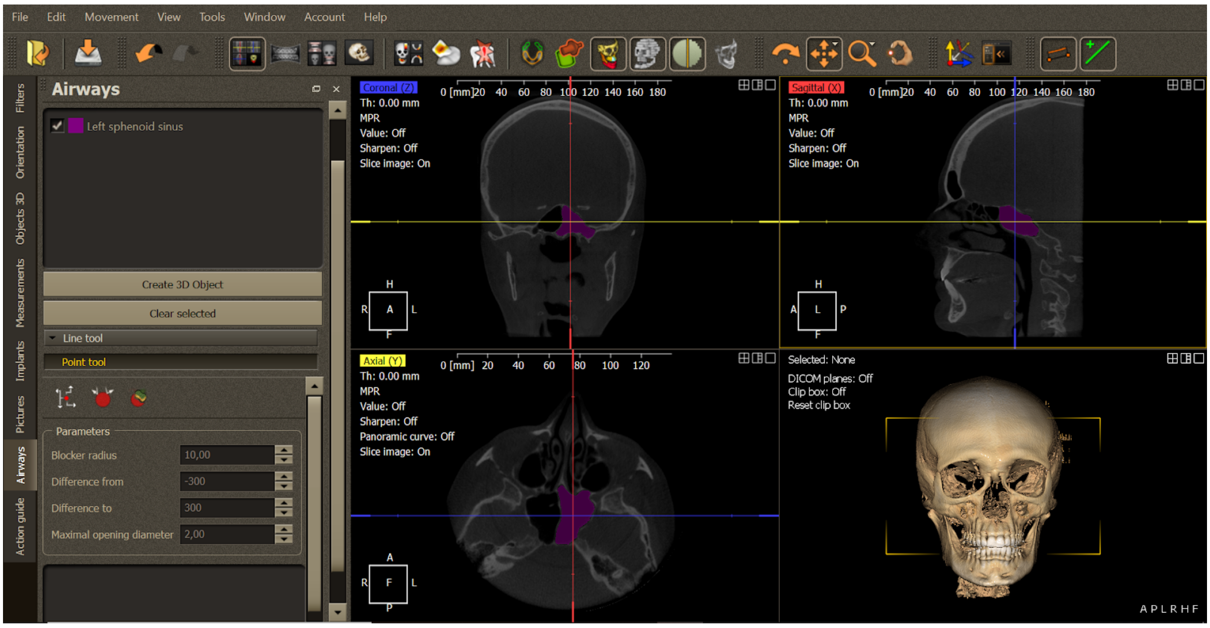
Fonte: Arquivo pessoal da autora.

Figura 15 - Delimitação do seio maxilar nos planos axial, sagital e coronal



Fonte: Arquivo pessoal da autora.

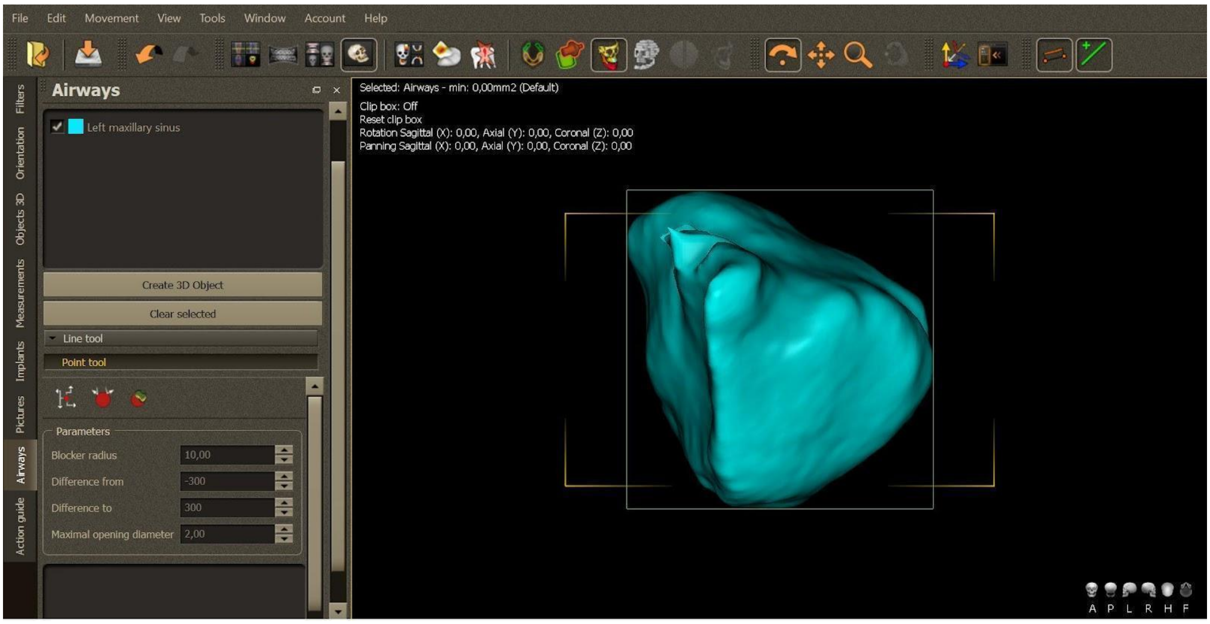
Figura 16 - Delimitação do seio esfenoidal nos planos axial, sagital e coronal



Fonte: Arquivo pessoal da autora.

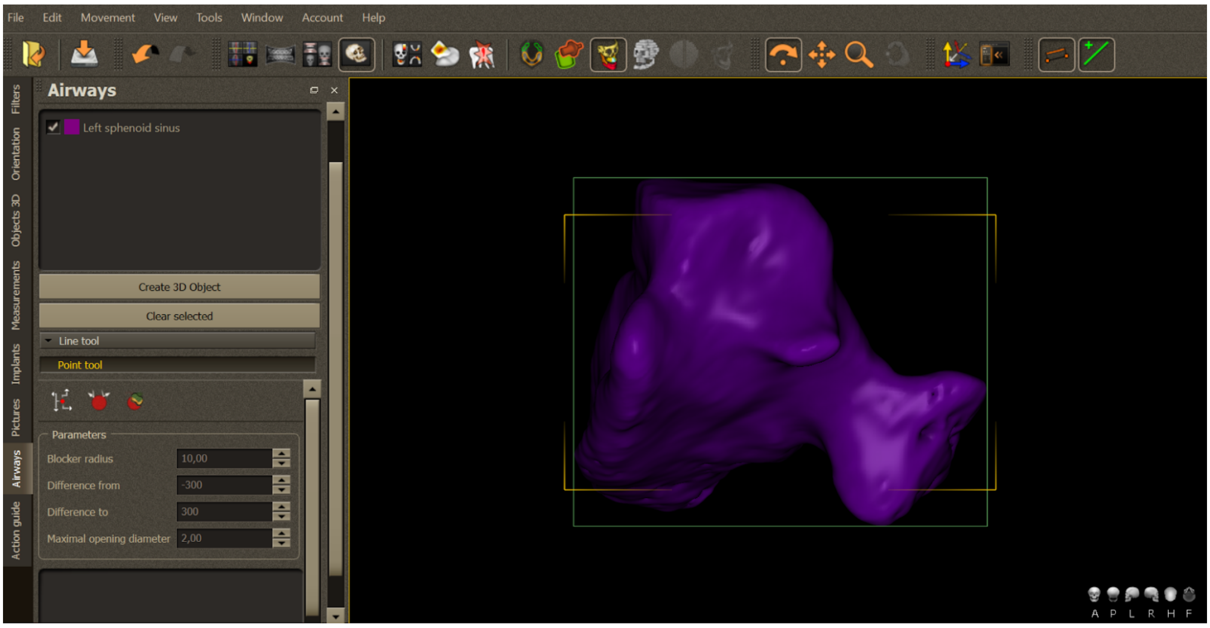
Depois de delimitados os seios nos três planos, foi realizada a reconstrução 3D dos seios maxilar e esfenoidal, na qual foram realizadas as medidas de volume e área (Figura 17-18).

Figura 17 - Reconstrução 3D de seio maxilar



Fonte: Arquivo pessoal da autora.

Figura 18. Reconstrução 3D de seio esfenoidal



Fonte: Arquivo pessoal da autora.

2.4 Análise estatística das medidas lineares

Inicialmente foram realizadas análises descritivas das variáveis do perfil da amostra com frequências absolutas e relativas. A reprodutibilidade das medidas inter e intra examinador foram avaliadas pelo TEM (technical error of measurement), rTEM (relative technical error of measurement) e R (coefficient of reliability). Foram então realizadas análises descritivas e exploratórias dos dados e a seguir, o teste t pareado foi utilizado nas comparações entre os lados esquerdo e direito em relação às medidas dos seios maxilar, frontal e esfenoidal. Foram calculadas as médias dos lados esquerdo e direito de cada participante e feita uma nova análise descritiva e exploratória para essas médias.

Para as comparações nos casos de duas categorias (sexo, cor da pele e IMC) foram utilizados o teste t de Student ou modelos lineares generalizados quando os dados não atenderam as pressuposições do teste. Para faixa de idade, que apresenta três categorias, foram utilizadas análise de variância (ANOVA) ou modelos lineares generalizados quando os dados não atenderam às pressuposições.

Foram também estimadas as médias das medidas com os respectivos intervalos de 95% de confiança em função do sexo e da faixa de idade. Todas as análises foram realizadas com auxílio do programa R e com nível de significância de 5%[2].

2.5 Análise estatística das medidas volumétricas

Inicialmente foram realizadas análises descritivas das variáveis do perfil da amostra com frequências absolutas e relativas. A reprodutibilidade das medidas inter e intra examinador foram avaliadas pelo TEM (technical error of measurement), rTEM (relative technical error of measurement) e R (coefficient of reliability). Foram então realizadas análises descritivas e exploratórias dos dados e a seguir, modelos lineares generalizados foram utilizados para analisar os lados esquerdo e direito em relação a área e o volume do seio maxilar e seio esfenoidal, considerando no modelo a dependência entre os lados do mesmo participante.

Foram calculadas as médias dos lados esquerdo e direito de cada participante e feita uma nova análise descritiva e exploratória para essas médias. Modelos lineares generalizados foram então utilizados para analisar o sexo, a faixa de idade, a cor da pele e o IMC em relação a área a o volume. Foram também estimadas as médias das medidas com os respectivos intervalos de 95% de confiança em função do sexo e da faixa de idade. Todas as análises foram realizadas com auxílio do programa R e com nível de significância de 5%[2].

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ANEXO A – AUTORIZAÇÃO PARA UTILIZAÇÃO DAS PUBLICAÇÕES 1-2

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UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Câmpus de Araraquara

FACULDADE DE ODONTOLOGIA

D E C L A R A Ç Ã O

Declaro para fins de pesquisa, que o projeto de pesquisa CAAE nº **47706121.4.0000.5416**, intitulado ***"SEIOS PARANASAIS E IDENTIFICAÇÃO HUMANA"***, de responsabilidade da Profª. Drª **MÔNICA DA COSTA SERRA**, foi aprovado por este CEP em Reunião de 10/09/2021.

Araraquara, 25 de outubro de 2021.

Andréa Gonçalves

Profa. Dra. Andréa Gonçalves
Coordenadora do CEP-FO/CAr.

Araraquara, 31 de março de 2022.

Franciéllen de Barros