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Anatomical and Pathological Assessment of the Maxillary Sinus Using CBCT Imaging: A Retrospective Descriptive Study

Anatomska i patološka analiza maksilarnog sinusa primjenom CBCT-a: retrospektivno-deskriptivna studija

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Abstract
A comprehensive understanding of the anatomy and pathology of the maxillary sinus is paramount for precise diagnosis and effective planning of dental interventions. Cone Beam Computed Tomography (CBCT) offers enhanced visualization of sinus structures, thus facilitating the identification of anatomical variations and pathological conditions which are critical for surgical and dental treatment strategies. **Materials and Methods:** This retrospective descriptive study analyzed 200 CBCT scans, comprising 400 maxillary sinuses from patients treated at the Faculty of Dentistry with Dental Clinical Center University of Sarajevo. The study assessed sinus dimensions, volumes, anatomical features, their relationships with adjacent anatomical structures, and the occurrence of pathological alterations. Furthermore, the patient's gender and dental status were studied in relation to these features. The sinus measurements were performed with Sidexis 4 software (Dentsply Sirona, Germany), which is intended for precise linear measurements in three orthogonal planes. **Results:** Significant differences were found in sinus width between patients with full dentition and those with partial or complete edentulism ($p<0.01$). Male participants exhibited larger mean sinus dimensions compared to females in all dimensions. The maxillary sinus floor was inferior to the nasal floor in 91.5% of cases. Various types of sinus membrane abnormalities were observed, with normal membrane thickness in 53.75% of cases. Sinus septa were most frequently located on the roof of the sinus, and their frequency varied significantly among patients with different dentition statuses. The study also identified 274 Haller cells and documented several pathological changes, with mucosal thickening exceeding 3 mm being the most common alteration. **Conclusion:** This radiographic study of Bosnian and Herzegovian population revealed significant anatomical variations and pathological changes in maxillary sinuses, thus emphasizing the importance of careful preoperative evaluation using CBCT for surgical planning in the posterior maxillary area. The findings highlight gender-based differences in sinus volumes, the impact of dentition status on sinus anatomy, and the prevalence of various pathological conditions, thus contributing to valuable insights in the field of maxillofacial radiology.

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Introduction

The maxillary sinus (MS), as the largest of the paranasal sinuses, is a critical anatomical structure in both dental and medical practice, particularly in the fields of implantology, endodontics, and oral surgery (1,2). Its complex relationship with maxillary teeth roots and proximity to oral and nasal structures necessitates precise diagnostic and therapeutic planning (3,4). In recent years, Cone Beam Computed Tomography (CBCT) has revolutionized the field of maxillo-

Uvod

Maksilarni sinus (MS) najveći među paranazalnim sinusima, ključna je anatomska struktura u dentalnoj i medicinskoj praksi, osobito u implantologiji, endodonciji i oralnoj kirurgiji (1, 2). Njegov kompleksni odnos s korijenima maksilarnih zuba te to što je blizu oralnih i nazalnih struktura zahtijevaju precizno dijagnostičko i terapijsko planiranje (3, 4). Posljednjih godina kompjutorska tomografija konusnoga snopa (CBCT) bila je prava revolucija u području maksilo-

facial radiology by offering superior visualization of the MS (5). Unlike traditional two-dimensional imaging, CBCT provides high-resolution, three-dimensional views that enable accurate measurement of sinus dimensions, volumetric assessment, and identification of both anatomical variations and pathological changes (6–8).

This enhanced diagnostic capability is crucial for detecting asymptomatic pathological alterations, such as mucosal thickening or cysts, which may go unnoticed in conventional imaging (3). While CBCT has significantly improved our understanding of MS anatomy and pathology, there remains inconsistency in the literature regarding the influence of factors such as sex, age, and dental status on sinus dimensions and pneumatization (9–12).

This study aimed to use CBCT imaging to conduct a detailed examination of the maxillary sinuses' dimensions, volume, anatomical features, and pathological states, with a focus on their clinical relevance in dental and surgical practices. The primary objectives of this research were to elucidate the measurements and characteristics of the maxillary sinuses. Specifically, the investigation endeavored to determine the height, width, length, and volume of the left and right maxillary sinuses while comparing these measurements among individuals with intact posterior teeth, patients with partial dentition, and those who were edentulous.

Additionally, the study sought to analyze the spatial relationship between the apices of the roots of posterior teeth and the floor of the MS, as well as the relationship between the MS floor and the floor of the nasal cavity. Another critical objective was to evaluate the dimensions and morphology of the sinus membrane. This research also focused on identifying prevalent anatomical variations of the MS and documenting their specific locations. This involved the classification of sinus pneumatization on a continuum ranging from mild to extremely severe, as well as examining the prevalence, height, location, and morphology of sinus septa across various dentition statuses.

Lastly, the study endeavored to recognize the frequency and characteristics of Haller cells, alongside identifying the most common pathological alterations present within the MS. The research aspired to enhance the understanding of these multifaceted aspects, employing CBCT imaging as a robust diagnostic modality for detailed evaluation.

Materials and Methods

Study Design

This retrospective descriptive study evaluated CBCT scans of the maxillary sinuses to investigate anatomical variations and pathological changes. The sample consisted of 200 randomly selected scans (400 maxillary sinuses) obtained from the Faculty of Dentistry with Dental Clinical Center University of Sarajevo database, collected between 2016 and 2020.

Ethical Approval

The study was conducted in compliance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee (approval number: 02-3-4-59-1-11/2020).

facijalne radiologije zato što je omogućila bolju vizualizaciju MS-a (5). Za razliku od tradicionalnih dvodimenzionalnih snimki, CBCT osigurava visokorezolucijske trodimenzionalne prikaze koji omogućuju precizno mjerenje dimenzija sinusa, volumetrijsku procjenu te identifikaciju kako anatomskih varijacija tako i patoloških promjena (6 – 8).

Poboljšana dijagnostika ključna je za otkrivanje asimptomatskih patoloških promjena, poput zadebljanja sluznice ili detekcije cista koje mogu proći neopaženo pri konvencionalnom snimanju (3). Iako je CBCT znatno unaprijedio naše razumijevanje anatomije i patologije MS-a, u literaturi i dalje postoji nedosljednost kad je riječ o utjecaju čimbenika poput spola, dobi i dentalnoga statusa na dimenzije i pneumatizaciju sinusa (9 – 12).

Cilj ovog istraživanja bio je da se primjenom CBCT-a detaljno ispitaju dimenzije, volumen, anatomske značajke i patološka stanja maksilarnih sinusa te procijeni njihova klinička relevantnost u stomatološkoj i kirurškoj praksi. Primarni ciljevi istraživanja bili su precizno odrediti visinu, širinu, duljinu i volumen lijevoga i desnoga maksilarnog sinusa te usporediti ove mjere među osobama s intaktnim postranim zubima te pacijentima s djelomičnom denticijom i onima bezubima.

Dodatno, u istraživanju je ispitan prostorni odnos vrhova korijena stražnjih zuba s dnom MS-a i odnos između dna MS-a i dna nosne šupljine. Još jedan ključni cilj bio je procijeniti dimenzije i morfologiju membrane sinusa te identificirati najčešće anatomske varijacije MS-a i njihovu specifičnu lokalizaciju. To je uključivalo klasifikaciju pneumatizacije sinusa u rasponu od blage do izražene te ispitivanje prevalencije, visine, lokalizacije i morfologije septi sinusa u odnosu na dentalni status pacijenata.

Naposljetku, istraživanjem se nastojala utvrditi učestalost i karakteristike Hallerovih stanica te prepoznati najčešće patološke promjene u MS-u. Također se željelo poboljšati razumijevanje navedenih aspekata maksilarnog sinusa, uz primjenu snimanja CBCT-om kao pouzdane dijagnostičke metode za njegovu detaljnu analizu.

Materijali i metode

Dizajn istraživanja

U ovom deskriptivno-retrospektivnom istraživanju analizirane su CBCT snimke maksilarnog sinusa kako bi se istražile anatomske varijacije i patološke promjene. Uzorak se sastojao od 200 nasumično odabranih snimki (400 maksilarnih sinusa) dobivenih iz baze podataka Stomatološkog fakulteta sa Stomatološkim kliničkim centrom Univerziteta u Sarajevu, prikupljenih između 2016. i 2020. godine.

Etičko odobrenje

Studija je provedena u skladu s Helsinškom deklaracijom i odobrilo ju je Institucionalno etičko povjerenstvo (broj odobrenja: 02-3-4-59-1-11/2020).

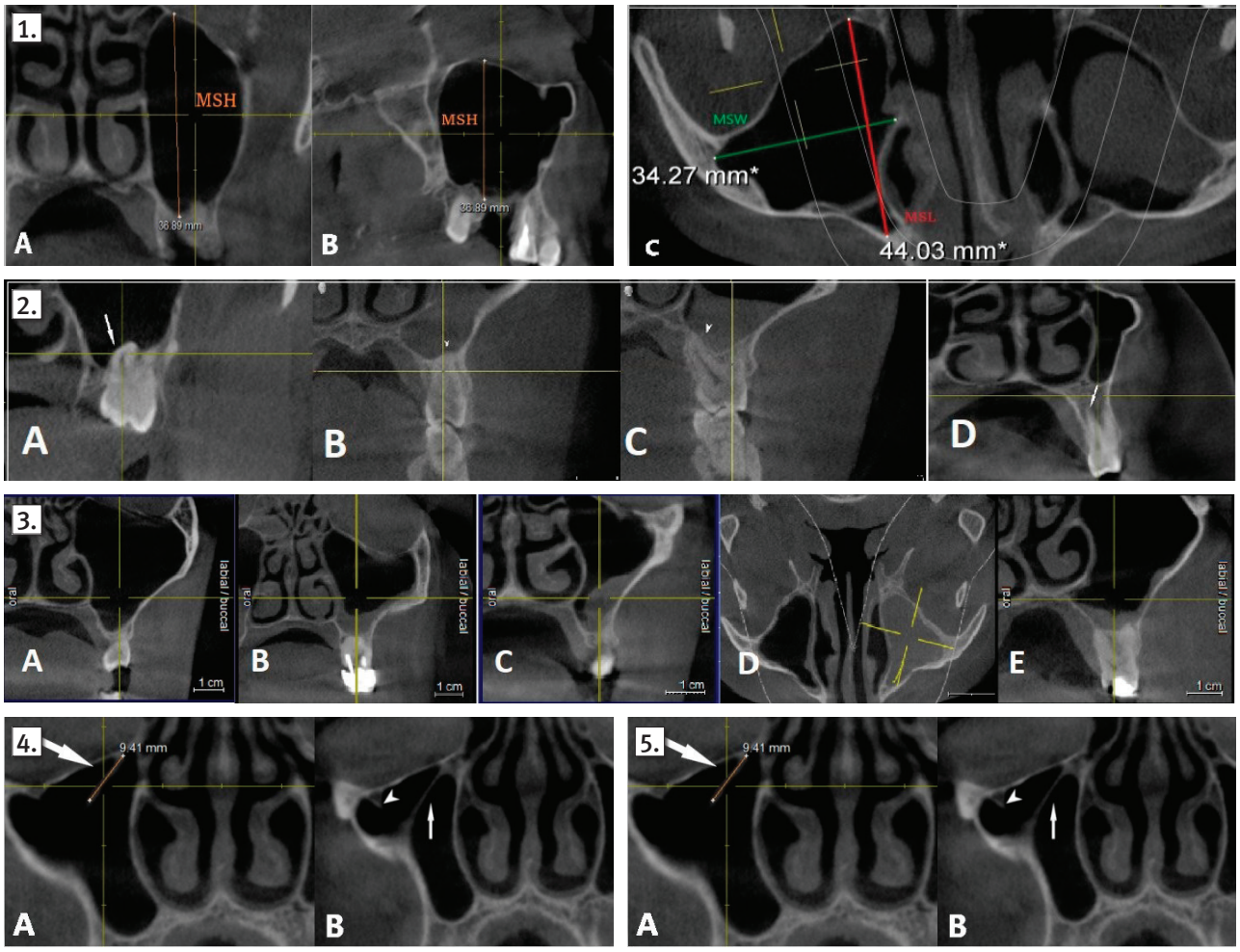

Figure 1 Linear measurements of the maxillary sinus on coronal, sagittal, and axial sections. (A) Height measured on the coronal section; (B) Height measured on the sagittal section (MSH); (C) Length (MSL) and width (MSW) measured on the axial section.
Slika 1. Linearna mjerenja maksilarnog sinusa na koronalnim, sagitalnim i aksijalnim presjecima: (A) visina izmjerena na koronalnom presjeku; (B) visina izmjerena na sagitalnom presjeku (MSH); (C) duljina (MSL) i širina (MSW) izmjerene na aksijalnom presjeku
Figure 2 Vertical relationship between the floor of the maxillary sinus and the apices of maxillary premolar and molar roots. (A) The root apex protrudes into the sinus cavity, with the distance (arrow) from the root apex to the sinus floor being negative; (B) The root apex is in close contact with the sinus, causing slight elevation of the sinus floor (arrowhead, distance = 0); (C) The root apex is in close contact with the sinus floor (arrowhead, distance = 0); (D) The root apex is located below the sinus floor (arrow, distance has a positive value).
Slika 2. Vertikalni odnos između dna maksilarnog sinusa i vrhova korijena pretkutnjaka i kutnjaka: (A) vrh korijena izbočen je u šupljinu sinusa, s negativnom udaljenošću (strelica) od vrha korijena do dna sinusa; (B) vrh korijena u neposrednom je kontaktu sa sinusom, uz blago podizanje dna sinusa (strelica, udaljenost = 0); (C) vrh korijena je u neposrednom kontaktu s dnom sinusa (strelica, udaljenost = 0); (D) vrh korijena smješten je ispod dna sinusa (strelica, udaljenost ima pozitivnu vrijednost).
Figure 3 Classification of maxillary sinus membrane thickening. (A) Healthy mucosa; (B) Flat thickening; (C) Semi-spherical thickening; (D) Mucocele-like thickening; (E) Undulating thickening.
Slika 3. Klasifikacija zadebljanja membrane maksilarnog sinusa: (A) zdrava sluznica; (B) ravno zadebljanje;(C) polukružno zadebljanje; (D) zadebljanje slično mukokeli; (E) valovito zadebljanje
Figure 4 Measurement of the height of Underwood's septa on coronal section. (A) Measurement of the height of Underwood's septa on a coronal image; (B) Example of a partial Underwood's septum (arrowhead) and a complete Underwood's septum (arrow).
Slika 4. Mjerenje visine Underwoodovih septi na koronalnom presjeku: (A) mjerenje visine Underwoodovih septi na koronalnoj slici; (B) primjer djelomičnog Underwoodova septuma (strelica) i potpunoga Underwoodova septuma (strelica)
Figure 5 Haller Cells. (A) Multiple Haller cells; (B) Linear measurement of the maximum vertical and horizontal dimensions of a Haller cell.
Slika 5. Hallerove stanice: (A) višestruke Hallerove stanice; (B) linearno mjerenje maksimalnih vertikalnih i horizontalnih dimenzija Hallerove stanice

Inclusion and Exclusion Criteria

Inclusion criteria consisted of technically adequate CBCT scans with clearly delineated borders of both maxillary sinuses. Exclusion criteria encompassed scans of patients with maxillary implants, and prior surgical interventions such as sinus augmentation, sinus lift procedures, and functional endoscopic sinus surgery (FESS).

Kriteriji za uključenje i isključenje

Kriteriji za uključenje obuhvaćali su tehnički ispravne snimke CBCT-om s jasno definiranim granicama obaju maksilarnih sinusa. Kriteriji za isključenje obuhvaćali su snimke pacijenata s maksilarnim implantatima te prethodnim kirurškim zahvatima poput augmentacije sinusa, podizanja dna sinusa i funkcionalne endoskopske kirurgije sinusa (FESS).

Imaging Technique

CBCT scans were performed using Orthophos SL and Galileos Comfort units (Dentsply Sirona, Germany) under standardized parameters: 5.0 mA, 98 kV, voxel size of 0.3–0.5 mm, and a maximum exposure time of 14.9 seconds.

Dimensions and Volume of the Maxillary Sinus

The measurement of sinus dimensions and volume was conducted using Sidexis 4 Software (Dentsply Sirona, Germany), allowing for precise linear measurements in three orthogonal planes (13). The height was determined by measuring the maximum distance between the superior and inferior sinus walls on coronal and sagittal sections. The width was assessed by calculating the distance between the most lateral and medial walls through axial sections of CBCT scan. Finally, the length was measured as the maximum distance between the anterior and posterior walls, also on axial sections. This systematic approach ensures an accurate and comprehensive evaluation of sinus dimensions (Figure 1).

The volume of the sinuses was calculated using geometric formulas. For spherical volumes, the formula used was $V = (4/3)\ \pi r^3$, where r represents the average radius of the sinus (14). For the pyramidal volumes, the formula applied was V= 1/3 A x h (14). The mean value derived from both methods was then utilized as the representative volume for each sinus.

The Relationship between the Roots of Posterior Teeth and the Sinus Floor

Using coronal cross-sectional images from CBCT scans, the vertical relationship between the MS floor and the apices of the roots of maxillary premolars and molars was analyzed. These were classified into four groups: the apex of the root protruding into the sinus cavity, the apex of the root in close contact with the sinus with minor elevation of the sinus floor, the apex of the root in close contact with the sinus floor, and the apex of the root below the sinus floor (Figure 2).

Morphology of the Maxillary Sinus Mucosa (Schneiderian Membrane)

The thickening of the sinus membrane was measured in millimeters on both sagittal and coronal cross-sections, from the sinus floor to the highest point of the thickened mucosa. Any thickness greater than 2mm was recorded as the presence of sinus membrane thickening. The thickening of the sinus membrane was classified according to the following height measurement index: Grade I 0-5mm; Grade II 5-10mm; Grade III 10-15mm Grade IV 15-20mm; Grade V > 20mm (15).

The morphology of the thickened sinus membrane was classified into five groups (Figure 3): normal membrane without thickening or uniform thickening without well-defined borders, semi-spherical thickening with well-defined borders, elevating at an angle of > 30° from the base or walls of the sinus, thickening resembling mucoceles (complete sinus opacification), and mixed flat and semi-spherical thickening–undulating thickening (16).

Tehnika snimanja

CBCT snimanja obavljena su uređajem Orthophos SL i Galileos Comfort (Dentsply Sirona, Njemačka) prema standardiziranim parametrima: 5,0 mA, 98 kV, veličina voxela 0,3 – 0,5 mm uz maksimalno vrijeme ekspozicije 14,9 sekunda.

Dimenzije i volumen maksilarnog sinusa

Mjerenje dimenzija i volumena sinusa provedeno je s pomoću softvera Sidexis 4 (Dentsply Sirona, Njemačka) zato što omogućuje precizna linearna mjerenja u trima ortogonalnim ravninama (13). Visina sinusa određena je mjerenjem maksimalne udaljenosti između gornjega i donjega zida sinusa na koronalnim i sagitalnim presjecima. Širina je procijenjena izračunavanjem udaljenosti između najlateralnijega i najmedijalnijega zida na aksijalnim presjecima CBCT snimki. Duljina je izmjerena kao maksimalna udaljenost između prednjega i stražnjega zida na aksijalnim presjecima. Takav sustavni pristup omogućuje preciznu i sveobuhvatnu procjenu dimenzija sinusa (slika 1.).

Volumen sinusa izračunat je korištenjem geometrijskih formula. Za sferne volumene to je formula $V = (4/3)\ \pi r^3$, gdje je r prosječni radijus sinusa (14). Za piramidalne volumene primijenjena je formula V= 1/3 A x h (14). Srednja vrijednost dobivena iz obiju metoda korištena je kao reprezentativni volumen za svaki sinus.

Odnos korijena stražnjih zuba i dna sinusa

Koristeći se koronalnim presjecima CBCT snimki, analiziran je vertikalni odnos između dna MS-a i vrhova korijena maksilarnih premolara i molara. Klasifikacija je uključivala četiri skupine: vrh korijena koji prodire u sinusnu šupljinu, vrh korijena u bliskom kontaktu sa sinusom s manjim podizanjem dna sinusa, vrh korijena u bliskom kontaktu s dnom sinusa te vrh korijena ispod dna sinusa (slika 2.).

Morfologija maksilarne sinusne sluznice (Schneiderova membrana)

Zadebljanje membrane sinusa mjereno je u milimetrima na sagitalnim i koronalnim presjecima, od dna sinusa do najviše točke zadebljane sluznice. Svako zadebljanje veće od 2 mm evidentirano je kao prisutnost zadebljanja membrane sinusa. Zadebljanje sinusne membrane klasificirano je prema sljedećem indeksu visine: I. stupanj (0 – 5 mm), II. stupanj (5 – 10 mm), III. stupanj (10 – 15 mm), IV. stupanj (15 – 20 mm) i V. stupanj (> 20 mm) (15).

Morfologija zadebljane sinusne membrane klasificirana je u pet skupina (slika 3.): normalna membrana bez zadebljanja ili homogeno zadebljanje bez jasno definiranih granica, polusferično zadebljanje s jasno definiranim granicama, elevacija pod kutom većim od 30° od baze ili zidova sinusa, zadebljanje nalik na mukokele (potpuna opacifikacija sinusa) te mješovito ravno i poluloptasto zadebljanje – valovito zadebljanje (16).

Evaluation of Anatomical Variations

The vertical relationship between the MS floor and nasal floor was analyzed using coronal sections. A horizontal reference line was drawn along the nasal floor, and the distance to the lowest point of the sinus floor was measured in millimeters (17,18).

Sinus septa were identified on axial, coronal, and sagittal sections and classified as complete (inserted on both walls) or partial (connected to only one wall). Their height and localization relative to teeth and sinus regions were recorded (19,20) (Figure 4).

Haller cells were identified on coronal sections; these ethmoidal air cells were located at the orbital floor and medial sinus wall. Dimensions were categorized as small (<2 mm), medium (2–4 mm), or large (>4 mm) (21) (Figure 5).

Pathological Changes in the Maxillary Sinus

In addition to evaluating the most common anatomical variations of MS, this study also recorded the most frequent pathological changes visible on CBCT scans. Abnormalities in the sinuses, which were the focus of this investigation, were documented in all three orthogonal planes through bilateral sinus analysis, and the changes were categorized as: (a) congenital changes (aplasia, hypoplasia), (b) malignant and benign tumors, (c) odontogenic lesions (benign odontogenic tumors and infections, odontogenic cysts), (d) bone lesions (ossifying fibroma, fibrous dysplasia), (e) traumatic lesions (bone fractures), (f) iatrogenic lesions, related to surgical interventions, such as oroantral communication, and (g) inflammatory lesions (mucosal thickening, retention cysts, opacifications, sinus polyps, and antroliths) (21).

The presence of periapical lesions in the region of posterior maxillary teeth was recorded when the lamina dura was absent or irregular in appearance, and when radiolucency indicated bone destruction around the root apex. In cases of multiple periapical lesions near the MS, only the lesions most closely related to the sinus were documented (23).

Location of Diagnosed Abnormalities

The location of diagnosed abnormalities was recorded based on their involvement of the anterior, posterior, superior, inferior, lateral, and/or medial walls of the sinus and classified according to the method proposed by Nishimura and Iizuka (22). The classification includes the following types: Type AP: involving both the anterior and posterior portions of the antrum; Type A: confined to the anterior portion of the antrum; Type P: confined to the posterior portion of the antrum; Type F: involving only the floor of the antrum.

In the vertical plane, mucosal and bone lesions were classified into the following types: Type S: involving the superior portion of the antrum and extending to its roof; Type I: confined to the inferior portion of the antrum.

Statistical Analysis

The data were primarily analyzed using descriptive statistics, along with statistical tests, including one-way analysis of variance (ANOVA), independent samples t-test, and the Mann-Whitney U test. Descriptive statistics were employed

Procjena anatomskih varijacija

Vertikalni odnos između dna MS-a i dna nosne šupljine analiziran je s pomoću koronalnih presjeka. Povučena je horizontalna referentna linija duž dna nosne šupljine te je izmjerena udaljenost do najniže točke dna sinusa u milimetrima (17, 18).

Septe sinusa identificirane su na aksijalnim, koronalnim i sagitalnim presjecima te klasificirane kao potpune (pričvršćene na oba zida) ili djelomične (povezane samo s jednim zidom). Zabilježena je njihova visina i lokalizacija u odnosu prema zubima i regijama sinusa (19, 20) (slika 4.).

Hallerove stanice identificirane su na koronalnim presjecima. Te etmoidalne zračne stanice bile su smještene u dnu orbite i medijalnom zidu sinusa. Dimenzije su kategorizirane kao male (< 2 mm), srednje (2 – 4 mm) ili velike (> 4 mm) (21) (slika 5.).

Patološke promjene maksilarnog sinusa

Osim procjene najčešćih anatomskih varijacija MS-a, u istraživanju su također dokumentirane najčešće patološke promjene vidljive na CBCT snimkama. Abnormalnosti sinusa evidentirane su u svim trima ortogonalnim ravninama na temelju bilateralne analize sinusa te su kategorizirane kao: (a) kongenitalne promjene (aplazija, hipoplazija), (b) maligni i benigni tumori, (c) odontogene lezije (benigni odontogeni tumori i infekcije, odontogene ciste), (d) koštane lezije (osificirajući fibrom, fibrotična displazija), (e) traumatske lezije (prijelomi kosti), (f) jatrogene lezije povezane s kirurškim zahvatima poput oroantralnih komunikacija i (g) upalne lezije (zadebljanje sluznice, retencijske ciste, opacifikacije, sinusni polipi i antroliti) (21).

Periapikalne lezije u području stražnjih gornjih zuba zabilježene su kada se primjećivao prekid kontinuiteta ili nepravilni izgled lamine dure te kada je radiolucentnost upozoravala na destrukciju kosti oko vrha korijena. U slučaju više periapikalnih lezija u blizini maksilarnoga sinusa, dokumentirane su samo one koje su bile u najbližoj relaciji sa sinusom (23).

Lokacija dijagnosticiranih abnormalnosti

Lokacija dijagnosticiranih abnormalnosti zabilježena je na temelju zahvaćenosti prednjega, stražnjega, gornjega, donjega, lateralnoga i/ili medijalnoga zida sinusa te klasificirana prema metodi koju su predložili Nishimura i Iizuka (22). Klasifikacija uključuje sljedeće tipove: tip AP zahvaća i prednji i stražnji dio antruma, tip A ograničen je na prednji dio antruma, tip P ograničen je na stražnji dio antruma, a tip F zahvaća samo dno antruma.

U vertikalnoj ravnini, mukozne i koštane lezije klasificirane su u sljedeće tipove: tip S zahvaća gornji dio antruma i proteže se do njegova krova, a tip I ograničen je na donji dio antruma.

Statistička analiza

Podatci su primarno analizirani korištenjem deskriptivne statistike, uz primjenu statističkih testova, uključujući jednosmjernu analizu varijance (ANOVA), t-test za nezavisne uzorke i Mann-Whitneyjev U-test. Deskriptivna statistika

to determine the frequencies and proportions of specific categories and subcategories. One-way analysis of variance was used because the independent variable (tooth presence) had more than two levels (all teeth, partial edentulism, and complete edentulism). The t-test was applied when analyzing differences in sinus dimensions between genders, representing an intergroup independent variable with two levels. The Mann-Whitney U test was used for the same analysis as a non-parametric alternative to the t-test for variables that did not meet the assumptions for parametric testing (homogeneity of variances between populations). All other analyses met the necessary assumptions for their application. Data processing was performed using MS Excel and IBM SPSS 23.

Results

This study analyzed CBCT scans of 200 patients (a total of 400 maxillary sinuses), comprising 99 males (49.5%) and 101 females (50.5%), aged between 15 and 74 years, with a mean age of 44.25 years. Among the total sample, 23 patients had a fully preserved dentition, 11 were completely edentulous, and 166 patients were partially edentulous.

A comparison of MS dimensions among patients with full dentition, partial edentulism, and complete edentulism revealed that the presence of teeth did not have a statistically significant effect on the height or length of the sinus ($p>0.05$). However, significant differences were observed in the width of the MS between the groups. Post-hoc testing using the Scheffe test indicated statistically significant differences in sinus width between patients with full dentition and those with complete edentulism ($p<0.01$), as well as between patients with full dentition and those with partial edentulism ($p<0.01$). Patients with full dentition demonstrated higher mean sinus width values compared to the other groups. These findings are presented in Table 1.

The analysis of sinus dimensions in relation to the participants' gender revealed significant differences, as presented in Table 2. Male participants exhibited larger mean sinus dimensions compared to female participants, including the height, length, width, and volume of both the right and left sinuses ($p<0.001$) for all parameters, except for the width of the right and left sinus, which was statistically significant at ($p<0.05$).

Descriptive analysis of the relationship between the MS floor, the nasal floor, and the roots of posterior teeth indicated that the sinus floor was inferior to the nasal floor in 91.5% of cases (366 sinuses). In the remaining 8.5% of cases, the sinus floor was either at the same level as or superior to the nasal floor (6.25% and 2.25%, respectively).

Furthermore, the analysis of the relationship between the tooth root apices and the MS revealed various types of interactions, including apical protrusion into the sinus cavity and close contact with the sinus floor. In this part of the study, a total of 189 CBCT scans were analyzed (patients with a complete dental arch and partial edentulism), as the remaining 11 scans demonstrated complete edentulism. The most common tooth with apices protruding into the maxillary sinus was the right second molar; the apex in close proximi-

korištena je za određivanje učestalosti i proporcija specifičnih kategorija i potkategorija. Jednosmjerna analiza varijance primijenjena je jer je nezavisna varijabla (prisutnost zuba) imala više razina (svi zubi, djelomična bezubost, potpuna bezubost). T-test korišten je za analizu razlika u dimenzijama sinusa između spolova, pri čemu je riječ o međugrupnoj nezavisnoj varijabli s dvjema razinama. Mann-Whitneyjev U-test primijenjen je za istu analizu kao neparametrijska alternativa t-testu za varijable koje nisu ispunjavale pretpostavke za parametrijsko testiranje (homogenost varijance između populacija). Sve ostale analize ispunjavale su potrebne pretpostavke za njihovu primjenu. Obrada podataka provedena je u programima MS Excel i IBM SPSS 23.

Rezultati

U istraživanju su analizirane CBCT snimke 200 pacijenata (ukupno 400 maksilarnih sinusa). od kojih je 99 bilo muškoga spola (49,5 %), a 101 ženskoga (50,5 %), u dobi od 15 do 74 godine, s prosječnom dobi od 44,25 godina. U ukupnom uzorku 23 pacijenta imala su potpuno očuvano zubalo, 11 je bilo potpuno bezubo, a 166 djelomično bezubo.

Usporedba dimenzija maksilarnih sinusa među pacijentima s potpunim zubalom, djelomičnom bezubosti i potpunom bezubosti pokazala je da prisutnost zuba nije statistički značajno utjecala na visinu ili duljinu sinusa ($p > 0,05$). No značajne razlike uočene su u širini sinusa između grupa. Post-hoc testiranje s pomoću Scheffeova testa pokazalo je statistički značajne razlike u širini sinusa između pacijenata s potpunim zubalom i onih s potpunom bezubosti ($p < 0,01$), te između pacijenata s potpunim zubalom i onih s djelomičnom bezubosti ($p < 0,01$). Pacijenti s potpunim zubalom imali su veće prosječne vrijednosti širine sinusa u usporedbi s ostalim grupama. Ti nalazi prikazani su u tablici 1.

Analiza dimenzija sinusa u odnosu na spol sudionika pokazala je značajne razlike, a nalaze se u tablici 2. Muški sudionici imali su veće prosječne dimenzije sinusa u usporedbi sa ženama, uključujući visinu, duljinu, širinu i volumen obaju sinusa (desnoga i lijevoga) ($p < 0,001$) za sve parametre, osim za širinu desnog i lijevog sinusa koja je bila statistički značajna na razini ($p < 0,05$).

Deskriptivna analiza odnosa između dna sinusa, dna nosne šupljine i korijena stražnjih zuba pokazala je da se dno sinusa nalazilo ispod dna nosne šupljine u 91,5 % slučajeva (366 sinusa). U preostalih 8,5 % slučajeva dno sinusa bilo je na istoj razini (6,25 %) ili iznad dna nosne šupljine (2,25 %).

Nadalje, analizom odnosa između vrhova korijena zuba i maksilarnog sinusa otkrivene su različite vrste interakcija, uključujući apikalnu protruziju u sinusnu šupljinu i blizak kontakt s dnom sinusa. U ovom dijelu studije analizirano je ukupno 189 CBCT snimki (pacijenti s kompletnim zubnim lukom i parcijalnom bezubosti), jer je na preostalih 11 utvrđena potpuna bezubost. Najčešći zub s vrhovima korijena koji prodiru u maksilarni sinus bio je drugi desni kutnjak, vrhovi korijena u bliskoj blizini sinusa, s laganim podizanjem sinusnog poda pronađeni su kod lijevog drugog kutnjaka, a vrhovi ispod razine poda sinusa najčešće su se nalazili kod

Table 1 Average dimensions (mm) of the right and left sinus based on dentition status
Tablica 1. Prosječne dimenzije (mm) desnoga i lijevoga sinusa prema statusu denticije

Sinus measure (mm) • Sinus mjerenje (mm)		Full Dentition • Potpuna denticija	Partial Edentulism • Parcijalna bezubost	Complete Edentulism • Potpuna bezubost	p
Right Sinus • Desni Sinus	Height • Visina	41.36	41.03	39.34	p > 0.05
	Length • Duljina	40.76	39.45	39.11	p > 0.05
	Width • Širina	31.59	28.33	25.94	p < 0.01*
	Volume • Volumen	27.22	23.67	21.23	p > 0.05
Left Sinus • Lijevi Sinus	Height • Visina	42.30	41.39	41.66	p > 0.05
	Length • Duljina	40.85	39.84	38.61	p > 0.05
	Width • Širina	31.67	28.96	26.37	p < 0.01*
	Volume • Volumen	27.92	24.66	22.11	p > 0.05

* Statistically significant at p < 0.01. Differences calculated using Scheffe's test. • Statistički značajno pri p < 0,01. Razlike izračunate korištenjem Scheffeova testa.

Table 2 Differences between male and female average sinus dimensions
Tablica 2. Razlike između muškaraca i žena u prosječnim dimenzijama sinusa

Sinus measure (mm) • Sinus mjerenje (mm)		Male (M) • Muškarci (M)	Female (F) • Žene (F)	p
Right Sinus • Desni Sinus	Height • Visina	43.19	38.77	< 0.001**
	Length • Duljina	40.32	38.87	< 0.001**
	Width • Širina	29.30	27.91	< 0.05*
	Volume • Volumen	26.38	21.58	< 0.001**
Left Sinus • Lijevi Sinus	Height • Visina	43.80	39.25	< 0.001**
	Length • Duljina	40.78	39.05	< 0.001**
	Width • Širina	29.91	28.42	< 0.05*
	Volume • Volumen	27.66	22.25	< 0.001**

* Statistically significant at p < 0.05; ** Statistically significant at p < 0.01. Differences calculated using t-test for independent samples and Mann-Whitney U test. • Statistički značajno pri p < 0,05; **Statistički značajno pri p < 0,01. Razlike izračunate korištenjem t-testa za nezavisne uzorke i Mann-Whitneyjeva U-testa.

Table 3 Descriptive indicators of root apex relationship with the sinus.
Tablica 3. Deskriptivni pokazatelji odnosa vrha korijena i sinusa

FDI tooth • FDI zub (n, %)	Root apex • Vrh korijena			
	protruding into sinus • protrudira u sinus (n, %)	close with sinus floor elevation • u blizini izbočenja sinusnoga dna (n, %)	close to sinus floor • blizu dna sinusa (n, %)	below sinus floor • ispod dna sinusa (n, %)
14 (n=125)	1 (0.1)	0 (0)	20 (2.05)	104 (10.67)
15 (n=110)	1 (0.1)	17 (1.74)	44 (4.51)	48 (4.92)
16 (n=97)	6 (0.61)	33 (3.38)	40 (4.10)	18 (1.84)
17 (n=115)	10 (1.02)	41 (4.20)	32 (3.25)	32 (3.28)
18 (n=52)	6 (0.61)	14 (1.43)	22 (2.52)	10 (1.02)
24 (n=103)	0 (0)	4 (0.41)	18 (1.84)	81 (8.31)
25 (n=106)	2 (0.2)	16 (1.64)	48 (4.92)	40 (4.10)
26 (n=79)	8 (0.82)	21(2.15)	35 (3.59)	15 (1.54)
27 (n=129)	5 (0.51)	53 (5.44)	43 (4.41)	28 (2.84)
28 (n=58)	7 (0.71)	10 (1.02)	25 (2.56)	16 (1.64)
n=974 (100)	46 (4.68)	209 (21.41)	327 (33.75)	392 (40.16)

Table 4 Frequency of sinus septa appearance
Tablica 4. Učestalost pojave sinusnih septi

Septa location • Položaj septa (n)		Full dentition • Potpuna denticija		Partial edentulism • Djelomična bezubost		Complete edentulism • Potpuna bezubost	
		Complete • Potpuna	Partial • Djelomična	Complete • Potpuna	Partial • Djelomična	Complete • Potpuna	Partial • Djelomična
Antral Septa • Antralna septa	Anterior • Prednja	8 (1.78)	2 (0.44)	30 (6.68)	18 (4.01)	1 (0.22)	1 (0.22)
	Middle • Srednja	1 (0.22)	6 (1.33)	26 (5.79)	27 (6.01)	3 (0.66)	1 (0.22)
	Posterior • Stražnja	4 (0.89)	1 (0.22)	48 (10.69)	11 (2.44)	3 (0.66)	1 (0.22)
Wall Septa • Septa na zidu	Lateral • Lateralna	2 (0.44)	1 (0.22)	21 (4.67)	17 (3.78)	1 (0.22)	1 (0.22)
	Medial • Srednja	1 (0.22)	3 (0.66)	5 (1.11)	7 (1.56)	1 (0.22)	1 (0.22)
	Anterior • Prednja	3 (0.66)	4 (0.89)	13 (2.89)	6 (1.33)	0 (0)	0 (0)
Septa on Sinus Roof • Septa na krovu sinusa		6 (1.33)	17 (3.78)	68 (15.14)	70 (15.59)	3 (0.66)	6 (1.33)
n=449		25 (5.54)	34 (7.54)	211(46.99)	156 (34.75)	12 (2.64)	11(2.43)
		59 (13.08)		367 (81.74)		23 (5.07)	

Table 5 Classification and distribution of mucosal thickening by grade with descriptive indicators of sinus membrane morphology and thickening
Tablica 5. Klasifikacija i distribucija zadebljanja sluznice prema stupnju s deskriptivnim pokazateljima morfologije i zadebljanja sinusne membrane

Mucosal thickening by grade (mm) • Zadebljanje sluznice prema stupnju (mm)	n (%)
Grade I (0-5mm) • I. stupanj (0 -5mm)	235 (58.75%)
Grade II (5-10 mm) • II. stupanj (5-10 mm)	69 (17.25%)
Grade III (10-15 mm) • III. stupanj (10-15 mm)	40 (10%)
Grade IV (15-20 mm) • IV. stupanj (15-20 mm)	20 (5%)
Grade V (>20 mm) • V. stupanj (>20 mm)	36 (9%)
Total • Ukupno	400 (100%)
Sinus membrane morphology • Morfologija sinusne membrane	**n (%)**
Normal membrane (no thickening) • Normalna membrana (bez zadebljanja)	215 (53.75%)
Flat thickening without well-defined margins • Ravno zadebljanje bez jasno definiranih granica	61 (15.25%)
Hemispherical thickening with well-defined margins * • Polukružno zadebljanje s dobro definiranim granicama*	64 (16%)
Mucocele-like thickening (complete sinus opacification) • Zadebljanje slično mukokeli (potpuna sinusna opacifikacija)	6 (1.5%)
Mixed flat and hemispherical mucosal thickening • Miješano ravno i polukružno zadebljanje	44 (11%)
Other (undefined) types of mucosal thickening • Drugi (nedefinirani) tipovi zadebljanja sluznice	10 (2.5%)
Total • Ukupno	400 (100%)

* Elevating at an angle >30° from the sinus floor or walls. • Uzdignuto na kut > 30° u odnosu prema dnu i zidovima sinusa.

ty to the sinus, with a slight elevation of the sinus floor, was found in the left second molar, while apices below the sinus floor level were most commonly found in the right first premolar.. These findings are detailed in Table 3.

In the analysis of sinus septa, the most frequently observed septa were located on the roof of the sinus, whereas septa on the medial sinus wall were the least common. The frequency of sinus septa varied significantly among patients with full dentition, partial edentulism, and complete edentulism, as detailed in Table 4.

A review of 200 CBCT scans identified a total of 274 Haller cells (Figure 5), with 141 located in the right MS and 133 in the left. Of these, 162 cells were solitary, 41 appeared in pairs, and 10 occurred in clusters of three cells. Based on size, 52 were classified as small (<2 mm), 139 as medium (2–4 mm), and 83 as large (>4 mm).

The prevalence of various types of sinus membrane abnormalities was also analyzed. Mucosal thickening was detected in several forms, with a normal membrane (no thickenprvoga desnog pretkutnjaka. Ti nalazi detaljno su prikazani u tablici 3.

Analiza septi maksilarnog sinusa pokazala je da su one najčešće uočene bile smještene na krovu sinusa, a one na medijalnom zidu sinusa bile su najrjeđe. Učestalost sinusnih septi značajno je varirala među pacijentima s potpunim zubalom, djelomičnom bezubosti i potpunom bezubosti, kako je prikazano u tablici 4.

Pregledom 200 CBCT snimki identificirane su ukupno 274 Hallerove stanice (slika 5.), od kojih je 141 bila smještena u desnome maksilarnom sinusu, a 133 u lijevome. Od toga su 162 stanice bile pojedinačne, 41 se pojavila u parovima, a 10 u grupama od triju stanica. Prema veličini, 52 su klasificirane kao male (< 2 mm), 139 kao srednje (2 – 4 mm), a 83 kao velike (> 4 mm).

Također je analizirana učestalost različitih vrsta abnormalnosti membrane sinusa. Zadebljanje sluznice otkriveno je u nekoliko oblika, pri čemu je normalna membrana (bez zadebljanja) uočena u 53,75 % slučajeva. Ostali oblici zade-

ing) observed in 53.75% of cases. Other types of thickening, including hemispherical and mucocele-like formations, were noted in fewer cases (Table 5). The analysis of mucosal thickness revealed the highest prevalence within Grade I, which accounted for 58.75% of sinuses (Table 5).

This study also analyzed pathological changes in the maxillary sinuses, documenting findings for 6 of the 13 recognized types of abnormalities. The most common alteration was mucosal thickening exceeding 3 mm, observed in 155 cases. Retention mucous cysts were identified in 20 patients. Additional findings included periapical lesions in 100 cases, oroantral communications in 7 cases, odontogenic cysts in 4 cases, and sinus opacifications in 3 cases. Conversely, tumors, polyps, antroliths, fibrous dysplasia, and ossifying fibromas were not detected in any of the scans.

Discussion

The MS represents a critical anatomical structure within the maxillofacial region, thus making the analysis of its anatomy and pathology essential, particularly in the context of pre-surgical planning for procedures such as dental implant placement and sinus lift surgeries (23). In our study, we evaluated the volume of the MS, its relationship with posterior teeth, the prevalence of Underwood's septa and Haller cells, as well as the most common pathological changes. These aspects have similarly been the focus of numerous studies investigating variations related to sex, age, and racial differences.

This study has demonstrated that the volume of the MS can be easily estimated using a straightforward mathematical formula based on its three linear dimensions: height, length, and width. The proposed method for assessing MS volume does not require expensive equipment, time-intensive procedures, or advanced software. Although the precise shape of the MS is challenging to determine, a purely mathematical analysis suggests that its geometry lies between spherical and pyramidal forms (14).

In consistency with our results, most published studies do not report significant differences in the dimensions of the left and right maxillary sinuses (9,12,24–26).

Our research, which included 23 patients with complete dentition, 11 edentulous patients, and 166 partially edentulous patients, revealed that the presence of teeth does not influence MS pneumatization. This aligns with the findings of Bornstein et al. (10), who analyzed CBCT images and investigated factors such as sex, age, sinus side, and dental status, finding no significant differences in sinus volume between dentate and edentulous individuals. Similarly, a CT-based study by Ariji et al. (11) found no significant effect of tooth loss on MS pneumatization in adults . They evaluated the sinus floor height relative to dentition and concluded that it is not directly associated with dental status, although changes in floor height were linked to age. Specifically, the floor height decreases until the age of 20, after which it increases, with these changes being independent of the presence or absence of teeth. Luz et al. (9) also found no influence between MS volume and dentition status but observed that men have

bljanja, uključujući polukružne i formacije slične mukokelama, zabilježeni su u manjem broju slučajeva (tablica 5.). Analiza debljine sluznice pokazala je najveću učestalost unutar I. stupnja (58,75 % sinusa) (tablica 5.).

Nadalje, u istraživanju su analizirane patološke promjene u maksilarnim sinusima, dokumentirajući nalaze za 6 od 13 prepoznatih vrsta abnormalnosti. Najčešća promjena bila je zadebljanje sluznice veće od 3 mm koje je uočeno u 155 slučajeva. Retencijske mukozne ciste identificirane su kod 20 pacijenata. Dodatni nalazi uključivali su periapikalne lezije u 100 slučajeva, oroantralne komunikacije u 7 slučajeva, odontogene ciste u 4 slučaja te zamućenja sinusa u 3 slučaja. S druge strane, tumori, polipi, antroliti, fibrodisplazija i osificirajući fibromi nisu otkriveni ni na jednoj snimci.

Rasprava

MS je ključna anatomska struktura unutar maksilofacijalne regije, što analizu njegove anatomije i patologije čini iznimno važnom, osobito u kontekstu planiranja kirurških zahvata poput postavljanja dentalnih implantata i podizanja sinusa (23). U našem istraživanju analizirali smo volumen maksilarnog sinusa, njegov odnos sa stražnjim zubima, prisutnost Underwoodovih septi i Hallerovih stanica te najčešće patološke promjene. Ti aspekti također su bili predmet mnogobrojnih studija čiji su autori istraživali varijacije u odnosu na spol, dob i rasne razlike.

U ovom istraživanju utvrđeno je da se volumen maksilarnog sinusa može jednostavno procijeniti matematičkom formulom temeljenom na trima linearnim dimenzijama: visini, duljini i širini. Predložena metoda za procjenu volumena maksilarnog sinusa ne zahtijeva skupu opremu, dugotrajne postupke ili napredni softver. Iako je točan oblik maksilarnog sinusa teško odrediti, čisto matematička analiza sugerira da se njegova geometrija nalazi između sferičnoga i piramidnoga oblika (14).

U skladu s našim rezultatima, u većini objavljenih studija autori ne izvještavaju o značajnim razlikama u dimenzijama lijevoga i desnoga maksilarnoga sinusa (9, 12, 24 – 26).

Naše istraživanje, koje je uključivalo 23 pacijenta s potpunim zubalom, 11 potpuno bezubih i 166 s djelomičnom bezubosti, pokazalo je da prisutnost zuba ne utječe na pneumatizaciju maksilarnog sinusa. To je u skladu s nalazima Bornsteina i suradnika (10) koji su analizirali CBCT snimke i istražili čimbenike poput spola, dobi, strane sinusa i dentalnoga statusa, no nisu pronašli značajne razlike u volumenu sinusa između osoba sa zubima i bez njih. Slično tomu, u CT-studiji Arija i suradnika (11) nije uočen značajan učinak gubitka zuba na pneumatizaciju maksilarnoga sinusa kod odraslih. Oni su procijenili visinu dna sinusa u odnosu prema denticiji i zaključili da visina nije izravno povezana s dentalnim statusom, iako su promjene u visini dna povezane s dobi. Konkretno, visina dna sinusa smanjuje se do dobi od 20 godina nakon čega raste, pri čemu su te promjene neovisne o prisutnosti ili odsutnosti zuba. Luz i suradnici (9) također nisu pronašli povezanost između volumena maksilarnog sinusa i dentalnoga statusa, ali su primijetili da muškarci

larger sinus volumes than women. Despite discrepancies in the literature, numerous studies emphasize the need for more precise definitions of pneumatization and larger sample sizes. Future research should include comparable numbers of dentate and edentulous patients, with clearly defined intervals after tooth extraction, to elucidate the impact of tooth loss on sinus volume (10).

Our study revealed a significant difference in MS dimensions between male and female patients, aligning with the findings of Bangi et al., Belgin et al., Akay et al., and Schriber et al. (23,24,27,28). In contrast, other authors, including Urooge et al., Kawakami et al., and Amine et al. (25,29,30), found no significant sex differences in MS dimensions.

Regarding the relationship between the MS floor and the nasal cavity floor, our findings align with the literature indicating that the sinus floor in adults typically lies below the level of the nasal cavity floor (31). Among our participants, the sinus floor was inferior to the nasal floor in 45.28% of cases on the right and 46.25% on the left. Sbordone et al. (17) assessed the relationship between these anatomical landmarks in partially and totally edentulous patients and reported no significant differences between the groups. Similarly, Cavalcanti et al. (18) analyzed the distance between the nasal cavity floor and the MS floor, noting that the type of tooth at the measurement site significantly influenced this distance. They found the shortest distances at the second molar site, while measurements at the second premolar and first molar sites showed no significant difference.

Kang et al. (32) retrospectively evaluated CBCT images to analyze the vertical relationship between maxillary tooth roots and the MS floor. They observed that the apices of the first and second molars frequently protruded into the sinus cavity, whereas the roots of the first and second premolars were commonly below the sinus floor, with no statistically significant differences between the right and left sides. Our study similarly found no significant differences between sides but yielded slightly different results (Table 3). Among our participants, the apices of the second molars were most frequently in close contact with the sinus floor or associated with minor sinus floor elevation. The apices of the first molars were also often in close contact with the sinus, accompanied by slight floor elevation. Jung and Cho (33) also noted that molars commonly extend into the sinus cavity, with the second molars protruding most frequently (36.7%), followed by the first molars (32.5%). If third molars were present on CBCT images, they exhibited variability across categories. For the first premolars, our findings were consistent with Kang et al. (32), while the roots of the second premolars were predominantly located either below the sinus floor or in close contact with it, with equal prevalence in both categories. These results align with the CBCT study by Kilic et al. (34), which reported the greatest distance between the first premolar and sinus floor and the shortest distance at the second molar.

Comparing findings from other studies and ours on the morphology and thickness of the Schneiderian membrane revealed diverse results. Recent CBCT-based studies report a higher prevalence of Schneiderian membrane thicken-

imaju veće sinuse u usporedbi sa ženama. Unatoč neslaganjima u literaturi, autori mnogih studija ističu potrebu za preciznijim definicijama pneumatizacije i većim uzorcima. Buduća istraživanja trebala bi uključiti usporedive brojeve osoba sa zubima i bez njih, uz jasno definirane vremenske intervale nakon ekstrakcije zuba kako bi se razjasnio utjecaj gubitka zuba na volumen sinusa (10).

Naše istraživanje otkrilo je značajne razlike u dimenzijama maksilarnog sinusa između muških i ženskih pacijenata, što je u skladu s nalazima Bangija i suradnika, Belgina i suradnika, Akaya i suradnika i Schribera i suradnika (23, 24, 27, 28). Suprotno tomu, drugi autori, uključujući Uroogea i suradnike, Kawakamija i suradnike i Aminea i suradnike (25, 29, 30), nisu pronašli značajne spolne razlike u dimenzijama maksilarnog sinusa.

Kad je riječ o odnosu između dna maksilarnog sinusa i dna nosne šupljine, naši rezultati u skladu su s onima u literaturi i upozoravaju na to da se dno sinusa kod odraslih obično nalazi ispod razine dna nosne šupljine (31). Među našim ispitanicima dno sinusa bilo je inferiorno u odnosu na dno nosne šupljine u 45,28 % slučajeva na desnoj strani i 46,25 % na lijevoj strani. Sbordone i suradnici (17) analizirali su odnos između tih anatomskih struktura kod djelomično i potpuno bezubih pacijenata te nisu ustanovili značajne razlike među skupinama. Slično tomu, Cavalcanti i suradnici (18) analizirali su udaljenost između dna nosne šupljine i dna maksilarnog sinusa, pri čemu su utvrdili da vrsta zuba na mjestu mjerenja značajno utječe na tu udaljenost. Najkraće udaljenosti pronašli su na mjestu drugog kutnjaka, a mjerenja na mjestima drugoga pretkutnjaka i prvoga kutnjaka nisu pokazala značajne razlike.

Kang i suradnici (32) retrospektivno su analizirali CBCT snimke kako bi procijenili vertikalni odnos između korijena maksilarnih zuba i dna sinusa. Utvrdili su da vrhovi korijena prvoga i drugoga kutnjaka često protrudiraju u sinusnu šupljinu, a korijeni prvoga i drugoga pretkutnjaka najčešće su smješteni ispod dna sinusa, bez statistički značajnih razlika između desne i lijeve strane. U našem istraživanju također nisu otkrivene značajne razlike između strana, ali dobiveni su nešto drukčiji rezultati (tablica 3.). Među našim ispitanicima vrhovi korijena drugoga kutnjaka najčešće su bili u bliskom kontaktu s dnom sinusa ili su bili povezani s blagim podizanjem dna sinusa. Vrhovi korijena prvoga kutnjaka također su često bili u bliskom kontaktu sa sinusom, uz blago podizanje dna sinusa. Jung i Cho (33) također su uočili da kutnjaci često protrudiraju u šupljinu sinusa, pri čemu su drugi kutnjaci najčešće protrudirani (36,7 %), a nakon njih slijede prvi kutnjaci (32,5 %). Treći kutnjaci, na CBCT snimkama, su pokazivali varijabilnost u različitim kategorijama. Za prve pretkutnjake naši su nalazi bili u skladu s istraživanjem Kanga i suradnika (32), dok su se korijeni drugih pretkutnjaka pretežno nalazili ili ispod dna sinusa ili u bliskom kontaktu s njim, s jednakom učestalošću u objema kategorijama. Ti se rezultati podudaraju s CBCT istraživanjem Kilica i suradnika (34) koji su izvijestili o najvećoj udaljenosti između prvoga pretkutnjaka i dna sinusa te najmanjoj udaljenosti kod drugoga kutnjaka.

Usporedba nalaza iz drugih studija i naše studije o morfologiji i debljini Schneiderove membrane pokazala je razli-

ing than earlier studies (15,35). CBCT imaging is considered more accurate than panoramic radiography for identifying membrane thickening and pathological changes in the posterior maxilla (36,37), possibly explaining the increased prevalence in recent reports. In our study, 53.75% of sinuses had healthy membranes, while 46.25% exhibited thickening (Table 5). These results align most closely with those of Ramanauskaite et al. (16), who reported 47% healthy membranes and 53% thickened membranes. Other studies have reported significantly higher prevalence rates of Schneiderian membrane thickening. For example, Genç et al. (38) observed a prevalence of 79.3%, noting a significantly higher incidence among males. Similarly, Schneider et al. (39) reported a thickening prevalence of 64.49%, with a higher frequency among men. Maska et al. (35) documented a prevalence of 93.1%, with 65.5% exceeding 5 mm in thickness. These differences could be attributed to varying inclusion criteria or thresholds for defining mucosal thickening. Many authors suggest that a threshold of 2 mm is appropriate for identifying thickened mucosa, which may have led to underestimations of mild thickening (35). Conversely, Amine et al. (30) reported that Schneiderian membrane thickening was the most common abnormality detected in their study (41%), using a threshold of >1 mm for thickening.

The presence of sinus septa in our study was a frequent finding, with a total of 449 septa (Table 4). The prevalence was 13.08% in fully dentate patients, 81.74% in partially edentulous patients, and 5.07% in completely edentulous patients. Orhan et al. (40) reported a higher prevalence of sinus septa in their study compared to previous research. Their study documented a total of 369 septa in 272 patients, with a frequency of 58%, where 53.9% occurred in partially edentulous patients, 3.2% in completely edentulous patients, and 3.8% in patients with mixed dentition. The frequency of sinus septa in partially edentulous patients was the most common finding in both our study and theirs. Kim et al. (20) reported a lower prevalence of sinus septa, with a frequency of 31.76% in edentulous patients (atrophic maxillary segments) and 22.61% in patients with complete dentition. Shahidi et al. (12) reported a prevalence of 45.4% in a sample of 396 maxillary sinuses. Regarding the anatomical location of sinus septa, most studies distinguish between anterior, middle, and posterior antral septa. Kim et al. (20) found that the majority of septa were located in the middle region of the MS floor, consistent with the findings of Genç et al. (38) and Krennmair et al. (41). In contrast, Koymen et al. (42), Velásquez-Plata et al. (43), and Shahidi et al. (12) most frequently reported anterior antral septa, while Dragan et al. (19) predominantly described posterior antral septa. In our study, the highest number of septa was located on the roof of the MS (37.83%), while anterior antral septa accounted for 13.35%, middle septa for 14.23%, and posterior septa for 15.12%. We also documented septa on the medial sinus wall (3.99%), lateral wall (9.55%), and anterior wall (5.77%). The literature indicates that most authors focus on antral septa as defined by Underwood (31), while secondary septa, which result from irregular pneumatization following tooth loss, are less frequently described. These findings regarding septa

čite rezultate. U novijim studijama temeljenima na CBCT-u uočena je veća prevalencija zadebljanja Schneiderove membrane u usporedbi s ranijim studijama (15, 35). CBCT snimanje smatra se preciznijim od panoramske radiografije u prepoznavanju zadebljanja membrane i patoloških promjena u stražnjem dijelu maksile (36, 37), što bi moglo objasniti veću prevalenciju u novijim istraživanjima. U našoj studiji 53,75 % sinusa imalo je zdravu membranu, a na 46,25 % zabilježeno je zadebljanje (tablica 5.). Ti rezultati najviše se podudaraju s istraživanjem Ramanauskaite i suradnika (16) koji su prijavili 47 % zdravih membrana i 53 % zadebljanih. Autori drugih studija izvijestili su o znatno većim stopama prevalencije zadebljanja Schneiderove membrane. Na primjer, Genç i suradnici (38) zabilježili su prevalenciju od 79,3 %, sa signifikantno većom učestalosti kod muškaraca. Slično tomu, Schneider i suradnici (39) prijavili su prevalenciju zadebljanja od 64,49 %, također s većom učestalošću kod muškaraca. Maska i suradnici (35) dokumentirali su prevalenciju od 93,1 %, pri čemu je 65,5 % slučajeva imalo zadebljanje veće od 5 mm. Te razlike mogle bi se pripisati različitim kriterijima uključivanja ili pragovima za definiranje zadebljanja sluznice. Mnogi autori predlažu prag od 2 mm kao odgovarajući za prepoznavanje zadebljane sluznice, što bi moglo rezultirati podcjenjivanjem blagih zadebljanja (35). S druge strane, Amine i suradnici (30) izvijestili su da je zadebljanje Schneiderove membrane bila najčešća abnormalnost otkrivena u njihovoj studiji (41 %), pri čemu su se koristili pragom od > 1 mm za definiranje zadebljanja.

Sinusna septa bila su čest nalaz u našoj studiji, s ukupno 449 septi (tablica 4.). Prevalencija je iznosila 13,08 % kod pacijenata s kompletnom denticijom, 81,74 % kod djelomično bezubih pacijenata i 5,07 % kod potpuno bezubih. Orhan i suradnici (40) prijavili su veću prevalenciju septi sinusa u svojem istraživanju u usporedbi s prethodnim istraživanjima. U njihovu istraživanju dokumentirano je ukupno 369 septi kod 272 pacijenta, s učestalošću od 58 %, pri čemu se 53,9 % pojavilo kod djelomično bezubih pacijenata, 3,2 % kod potpuno bezubih i 3,8 % kod pacijenata s mješovitom denticijom. Najčešći nalaz u objema studijama bila je prisutnost septi sinusa kod djelomično bezubih pacijenata. Kim i suradnici (20) prijavili su nižu prevalenciju septi sinusa, s učestalošću od 31,76 % kod bezubih pacijenata (atrofični segmenti maksile) i 22,61 % kod onih s kompletnom denticijom. Shahidi i suradnici (12) izvijestili su o prevalenciji od 45,4 % u uzorku od 396 maksilarnih sinusa. Kad je riječ o anatomskoj lokaciji septi sinusa, u većini studija autori razlikuju prednje, srednje i stražnje antralne septe. Kim i suradnici (20) otkrili su da je većina septi smještena u središnjem dijelu dna maksilarnog sinusa, što je u skladu s nalazima Gença i suradnika (38) i Krennmaira i suradnika (41). Suprotno tomu, Koymen i suradnici (42), Velásquez-Plata i suradnici (43) te Shahidi i suradnici (12) najčešće su prijavljivali prednje antralne septe, a Dragan i suradnici (19) dominantno su opisivali stražnje antralne septe. U našoj studiji najveći broj septi bio je smješten na krovu maksilarnog sinusa (37,83 %), a prednje antralne septe činile su 13,35 %, srednje 14,23 %, a stražnje 15,12 %. Također smo dokumentirali septe na medijalnom zidu sinusa (3,99 %), lateralnom zidu (9,55 %) i prednjem zi-

located on the roof of the MS are not extensively documented in the literature. Most authors investigate sinus septa due to their clinical significance in surgical interventions such as implant placement or sinus lift procedures. This may explain the lack of data on septa located on the sinus roof.

The prevalence of Haller cells varies significantly in the literature, ranging from 2.7% to 45.1% (44,45). This variability likely arises from inconsistent definitions of Haller cells. Bolger et al. (44) define Haller cells as any cell located between the ethmoid bulla, *lamina orbitalis* of the ethmoid bone, and the orbital floor. Kainz et al. (46) define them as cells within the orbital floor. Additional factors influencing prevalence variations include the age of subjects, racial background, and imaging modality (47). Our study adopted the criteria for identifying Haller cells based on the CBCT studies by Mathew et al. (48) and Friedrich et al. (21). Friedrich et al. (21) reported a prevalence of 23.62%, while Mathew et al. (48) reported a prevalence of 60% (48). In our study, the prevalence of Haller cells was 70%, closely aligning with Mathew et al.'s findings. Khojastepour et al.(49) reported a prevalence of 41.6% in their CBCT study and associated the presence of Haller cells with rhinosinusitis. Stackpole et al. (50), in a CT study, reported a prevalence of 34.4% and emphasized that Haller cells could act as anatomical obstructions within the ostiomeatal complex.

While examining pathological changes in the MS, our study identified the most common abnormality such as sinus membrane thickening (>3 mm), observed with a frequency of 46.25%. This finding is consistent with the majority of studies evaluating pathological changes in the MS, which also report sinus membrane thickening as the most frequently documented abnormality (16,30,51–53). Other pathological findings in our study included periapical lesions (25%), retention cysts (5%), iatrogenic oroantral communications (1.75%), odontogenic cysts (1%), and complete sinus opacification (0.75%).

In comparing the results of pathological changes identified in the MS, it is important to consider both the inclusion criteria of our study and those of other authors. In this study, we evaluated both anatomical variations and pathological changes of the MS, suggesting that the pathological changes observed among our subjects were incidental. Cha et al. (51) reported incidental pathological changes identified during CBCT analysis, focusing solely on sinus membrane thickening. Similarly, Amine et al. (30), in a study evaluating both anatomical variations and pathological changes of the MS, reported frequencies of sinus membrane thickening, polyps, and cysts at 20.33%, sinus hypoplasia at 11.66%, and complete sinus opacification at 4%.

Tadinada et al. (54) conducted a comparative evaluation of the MS using CBCT and panoramic radiographs, reporting an overall prevalence of pathological changes at 72%. Pazera et al. (52) analyzed CBCT images of orthodontic patients, reporting a prevalence of 46.8% for pathological changes, of which 3.6% represented acute inflammatory or allergic conditions, while 43.1% were attributed to chronic inflammatory or allergic conditions. Thus, when interpreting variations in the results concerning pathological changes

du (5,77 %). Prema podatcima iz literature, većina autora fokusira se na antralne septe kako ih je definirao Underwood (31), a sekundarne septe, koje nastaju zbog nepravilne pneumatizacije nakon gubitka zuba, rjeđe su opisane. Nalazi vezani uz septe smještene na krovu maksilarnoga sinusa nisu široko dokumentirane u literaturi. Većina autora istražuje septe sinusa zbog njihove kliničke važnosti u kirurškim zahvatima, poput postavljanja implantata ili podizanja dna sinusa. To bi moglo objasniti nedostatak podataka o septama smještenima na krovu sinusa.

Prevalencija Hallerovih stanica značajno varira u literaturi – od 2,7 % do 45,1 % (44, 45). Ta varijabilnost vjerojatno proizlazi iz nekonzistentnih definicija tih stanica. Bolger i suradnici (44) definiraju ih kao bilo koju stanicu smještenu između ethmoidne bule, *lamina orbitalis* ethmoidne kosti i dna orbite. Kainz i suradnici (46) definiraju ih kao stanice unutar dna orbite. Dodatni čimbenici koji utječu na razlike u prevalenciji uključuju dob ispitanika, rasno podrijetlo i korištenu vrstu radiografskih snimki (47). U našoj su se studiji kriteriji za identifikaciju Hallerovih stanica temeljili na CBCT studijama Mathewa i suradnika (48) te Friedricha i suradnika (21). Friedrich i suradnici (21) izvijestili su o prevalenciji od 23,62 %, a Mathew i suradnici (48) prijavili su prevalenciju od 60 %. U našoj studiji prevalencija Hallerovih stanica iznosila je 70 %, što se najviše podudara s nalazima Mathewa i suradnika. Khojastepour i suradnici (49) u svojoj studiji o CBCT-u izvijestili su o prevalenciji od 41,6 % te povezali prisutnost Hallerovih stanica s rinosinusitisom. Stackpole i suradnici (50) u CT istraživanju prijavili su prevalenciju od 34,4 % i istaknuli da Hallerove stanice mogu djelovati kao anatomske opstrukcije unutar ostiomeatalnog kompleksa.

Pri ispitivanju patoloških promjena u maksilarnom sinusu, najčešće uočena abnormalnost u našem istraživanju bilo je zadebljanje membrane sinusa (> 3 mm), s učestalošću od 46,25 %. Taj nalaz u skladu je s većinom studija koje su proučavale patološke promjene u maksilarnom sinusu, a u kojima se također navodi zadebljanje membrane sinusa kao najčešće dokumentirana abnormalnost (16, 30, 51 – 53). Ostali patološki nalazi u našem istraživanju uključivali su periapikalne lezije (25 %), retencijske ciste (5 %), jatrogene oroantralne komunikacije (1,75 %), odontogene ciste (1 %) i potpunu opacifikaciju sinusa (0,75 %).

Tijekom usporedbe rezultata patoloških promjena identificiranih u maksilarnom sinusu (MS), važno je uzeti u obzir kriterije za uključenje u našoj studiji i u studijama drugih autora. U ovoj smo studiji procjenjivali i anatomske varijacije i patološke promjene MS-a, što sugerira da su patološke promjene zabilježene kod naših ispitanika bile slučajne. Cha i suradnici (51) izvijestili su o slučajnim patološkim promjenama identificiranima tijekom CBCT analize, fokusirajući se isključivo na zadebljanje membrane sinusa. Slično tomu, Amine i suradnici (30) u istraživanju u kojemu su procjenjivali i anatomske varijacije i patološke promjene MS-a, prijavili su učestalost zadebljanja membrane sinusa, polipa i cista od 20,33 %, hipoplaziju sinusa od 11,66 % te potpunu opacifikaciju sinusa od 4 %.

Tadinada i suradnici (54) proveli su komparativnu evaluaciju MS-a s pomoću CBCT-a i panoramskih snimki te

in the MS, the primary focus and scope of each study must be considered.

The scope of our study regarding MS pathology aligns closely with the study by Rege et al. (53), though their research exclusively analyzed pathological changes in the MS using CBCT images. Rege et al. (53) reported sinus membrane thickening (66%), retention mucous cysts (10.1%), complete sinus opacification (7.8%), polyps (5.6%), antroliths (3.2%), oroantral communications (2.2%), traumatic fractures (1.4%), inflammatory and odontogenic cysts (0.7%), and even tumors with an incidence of 0.4%. They further noted that the most frequently observed abnormalities were located on the inferior sinus wall, while the superior wall was the least affected (53). These findings are consistent with the results of our study concerning the anatomical distribution of pathological changes in the MS.

Conclusion

Our radiographic study of the Bosnian and Herzegovian population yielded several key findings. No significant differences were found between the volumes of the left and right maxillary sinuses. The largest sinus volume was noted in patients with complete dentition, but these results require further confirmation due to the unequal distribution of participants and the lack of standardized timing regarding tooth extractions.

Male participants exhibited significantly larger MS volumes than females. The sinus floor was typically below the nasal floor, with the first premolars being the furthest from the sinus floor, while second molars were the closest.

Mucosal thickening over 3 mm was the most common pathological change, predominantly presenting as flat thickening with unclear margins. Sinus septa showed considerable variation, mostly located at the sinus roof, particularly in partially edentulous patients.

A high prevalence of Haller cells was observed, but no link was found between their presence and maxillary rhinosinusitis. About half of the CBCT scans showed pathological changes, with common findings including retention mucous cysts, complete sinus opacifications, and periapical lesions.

The variability of anatomical and pathological findings underlines the necessity for careful preoperative evaluation of the posterior maxillary area, with CBCT serving as the gold standard for assessing MS anatomy in surgical contexts.

Conflict of interest: The authors declare that there is no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

izvijestili o ukupnoj prevalenciji patoloških promjena od 72 %. Pazera i suradnici (52) analizirali su CBCT snimke ortodontskih pacijenata te prijavili prevalenciju patoloških promjena od 46,8 %, od čega je 3,6 % pokazivalo akutna upalna ili alergijska stanja, a 43,1 % bilo je povezano s kroničnim upalnim ili alergijskim stanjima. Stoga, pri interpretaciji varijacija u rezultatima vezanima za patološke promjene MS-a, ključno je uzeti u obzir primarni fokus i opseg svake studije.

Opseg naše studije o patologiji MS-a najbliži je studiji Regea i suradnika (53), iako su oni isključivo analizirali patološke promjene u MS-u koristeći se slikama CBCT-a. Rege i suradnici (53) izvijestili su o zadebljanju membrane sinusa (66 %), retencijskim mukoznim cistama (10,1 %), potpunoj opacifikaciji sinusa (7,8 %), polipima (5,6 %), antrolitima (3,2 %), oroantralnim komunikacijama (2,2 %), traumatskim prijelomima (1,4 %), upalnim i odontogenim cistama (0,7 %) te o tumorima s incidencijom od 0,4 %. Također su uočili da su najčešće abnormalnosti bile smještene na donjem zidu sinusa, a gornji je zid bio najrjeđe pogođen (53). Ti nalazi u skladu su s rezultatima naše studije kad je riječ o anatomskoj distribuciji patoloških promjena u MS-u.

Zaključak

U našoj radiografskoj studiji populacije Bosne i Hercegovine nekoliko je ključnih nalaza. Nisu utvrđene značajne razlike u volumenima lijevoga i desnoga maksilarnog sinusa. Najveći volumen sinusa zabilježen je kod pacijenata s potpunom denticijom, no ti rezultati zahtijevaju daljnju potvrdu zbog neujednačene distribucije sudionika i nedostatka standardiziranog vremenskog okvira u vezi s vađenjem zuba.

Muški ispitanici imali su značajno veće volumene maksilarnih sinusa u usporedbi sa ženama. Dno sinusa obično se nalazilo ispod nosnoga poda, pri čemu su prvi pretkutnjaci bili najudaljeniji od dna sinusa, a drugi kutnjaci bili su najbliži.

Zadebljanje sluznice veće od 3 mm bilo je najčešća patološka promjena i uglavnom se manifestirala kao ravno zadebljanje s nejasnim rubovima. Septe sinusa pokazale su značajnu varijabilnost, pri čemu su se većinom nalazile na krovu sinusa, osobito kod djelomično bezubih pacijenata.

Zabilježena je visoka prevalencija Hallerovih stanica, ali nije utvrđena povezanost njihove prisutnosti s maksilarnim rinosinusitisom. Na otprilike 50 posto CBCT snimki uočene su patološke promjene, pri čemu su najčešći nalazi bili retencijska mukozna cista, potpuna opacifikacija sinusa i periapikalne lezije.

Varijabilnost anatomskih i patoloških nalaza pokazuje da je prijeko potrebna pozorna preoperativna evaluacija stražnje maksilarne regije, pri je čemu CBCT zlatni standard za procjenu anatomije maksilarnog sinusa u kirurškim kontekstima.

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Sažetak

Izvrsno razumijevanje anatomije i patoloških promjena maksilarnog sinusa ključno je za preciznu dijagnostiku i učinkovito planiranje stomatoloških intervencija. Kompjutorska tomografija konusnoga snopa (CBCT) omogućuje poboljšanu vizualizaciju struktura sinusa, što olakšava prepoznavanje anatomskih varijacija i patoloških stanja bitnih za kirurške i stomatološke terapijske strategije. **Materijali i metode:** U ovoj retrospektivno-deskriptivnoj studiji analizirano je je 200 CBCT snimki i pregledano 400 maksilarnih sinusa pacijenata liječenih na Stomatološkom fakultetu Sveučilišta u Sarajevu. Analizirani su dimenzije i volumen sinusa, anatomske značajke, njihovi odnosi s okolnim anatomskim strukturama te prisutnost patoloških promjena. Također je ispitana povezanost spola i dentalnoga statusa pacijenata s navedenim parametrima. Mjerenja sinusa provedena su korištenjem softvera Sidexis 4 (Dentsply Sirona, Njemačka) koji je dizajniran za precizna linearna mjerenja u trima ortogonalnim ravninama. **Rezultati:** Ustanovljene su značajne razlike u širini sinusa između pacijenata s potpunom denticijom i onih s djelomičnom ili potpunom bezubosti ($p < 0,01$). Ispitanici su imali veće prosječne dimenzije sinusa u svim smjerovima u usporedbi s ispitanicama. Sinusno dno je inferiorno u odnosu na dno nosne šupljine u 91,5 % slučajeva. Uočene su različite vrste abnormalnosti membrane sinusa, pri čemu je njezina normalna debljina zabilježena kod 53,75 % ispitanika. Septe unutar sinusa najčešće su bile na krovu sinusa, a njihova se učestalost značajno razlikovala među pacijentima s različitim dentalnim statusima. U studiji su također identificirane 274 Hallerove stanice te je dokumentirano više patoloških promjena, a najčešće je bilo zadebljanje sluznice veće od 3 mm. **Zaključak:** U ovoj radiološkoj studiji populacije Bosne i Hercegovine otkrivene su značajne anatomske varijacije i patološke promjene maksilarnih sinusa pa je istaknuta važnost detaljne preoperativne procjene CBCT metodom za kirurško planiranje u stražnjoj maksilarnoj regiji. Nalazi upućuju na spolne razlike u volumenu sinusa, utjecaj dentalnoga statusa na anatomiju sinusa te prevalenciju različitih patoloških stanja, a pružaju i vrijedne podatke vezane za područje maksilofacijalne radiologije.

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