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Metabolic imaging of head and neck lesions: Differentiating dental and maxillofacial conditions using positron emission tomography/computed tomography

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MAIN POINTS

- Malignant dentomaxillofacial lesions demonstrated significantly higher FDG uptake (mean SUVmax =12.5) than all non-malignant conditions.
- Among benign pathologies, maxillary sinus diseases and periodontal infections showed moderate FDG uptake, which may mimic malignancy.
- TMJ disorders and dental artifacts exhibited minimal metabolic activity, aiding in their differentiation from true lesions.
- This study highlights the value of SUVmax comparisons to avoid misinterpretation of FDG-PET/CT in the head and neck region.
- The integration of CT/MRI with PET/CT improves diagnostic accuracy in differentiating benign and malignant dentomaxillofacial conditions.

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ABSTRACT

Aim: Fluorine-18-labeled fluoro-2-deoxy-D-glucose positron emission tomography/computed tomography (FDG-PET/CT) is an essential oncologic imaging modality, but its uptake patterns may also be seen in benign inflammatory or structural oral conditions, leading to diagnostic confusion. This study aims to compare metabolic activity with maximum standardized uptake value (SUVmax) among common dento-maxillofacial conditions---dental artifacts, periodontal infections, maxillary sinus pathologies, and temporomandibular joint (TMJ) disorders---against confirmed malignant lesions, to guide differential diagnosis and improve clinical interpretation.

Materials and Methods: A total of 100 FDG-PET/CT scans were retrospectively analyzed. Inclusion criteria comprised pre-treatment scans with available CT or magnetic resonance imaging (MRI) acquired within four weeks. Patients were categorized into five groups: Dental Artifacts (n=19), Periodontal Infections (n=23), Maxillary Sinus Pathologies (n=21), TMJ Pathologies (n=19), and Malignant Dento-maxillofacial Lesions (n=18; control group). All scans were reviewed by an oral and maxillofacial radiologist and a radiologist. SUVmax were calculated using a 42% threshold. Statistical analyses were conducted using Kruskal-Wallis and Mann-Whitney U tests with Bonferroni correction.

Results: Significant differences in SUVmax were observed across all groups (χ^2 = 77.4, p<0.000001). The malignant lesion group demonstrated the highest metabolic activity (mean SUVmax = 12.5 ± 3.0), significantly greater than all other groups (p<0.000001). Among non-malignant conditions, maxillary sinus pathologies showed the highest SUVmax (4.2 ± 1.0), followed by periodontal infections (3.5 ± 0.8). TMJ pathologies and dental artifacts exhibited the lowest FDG uptake (2.0 ± 0.6 and 2.5 ± 0.7, respectively), suggesting minimal metabolic activity.

Conclusion: This study confirms that malignant dento-maxillofacial lesions exhibit significantly higher FDG uptake compared to inflammatory and mechanical conditions. Understanding these uptake patterns is crucial to avoiding false-positive interpretations, especially in oncologic patients. Multimodal imaging and interdisciplinary evaluation are recommended for accurate differentiation of dental and maxillofacial pathologies in FDG-PET/CT interpretation.

Keywords: FDG-PET/CT, SUVmax, Dento-maxillofacial lesions, Oral cancer, Metabolic imaging

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INTRODUCTION

Fluorine-18-labeled fluoro-2-deoxy-D-glucose-positron emission tomography/computed tomography (FDG-PET/CT) is important in the detection, treatment and follow-up for malignant diseases. This imaging technique provides molecular-level information, allowing early detection of disease activity. It is recognized as a reliable and precise tool for diagnosing and quantifying disease burden, especially in clinical settings. Recent advancements have broadened its clinical use in infectious and inflammatory conditions. The distribution of FDG in these diseases is based on the same mechanisms as in malignancies, characterized by increased cellular metabolism [1,2].

All cells use glucose for energy, but most prefer the more efficient aerobic oxidative phosphorylation. Cancer cells, however, favor the less efficient glycolytic pathway even when oxygen is present. They meet their high glucose demand by increasing the active glucose transporter (GLUT), leading to higher FDG uptake. Once inside the cell, glucose is phosphorylated for further processing, while excess is expelled after dephosphorylation [2,3]. FDG, gets trapped inside cancer cells because it can't be processed further and isn't expelled, resulting in high intracellular concentration. This was initially thought to be specific to cancer cells, but it was discovered that immune cells also use this mechanism, causing false positives in FDG-PET/CT scans [1,4,5].

This manuscript has two primary aims. The first aim is to guide medical radiologists in accurately distinguish dental lesions from potential metastases. By presenting detailed case-based illustrations, the manuscript seeks to prevent misdiagnosis, particularly in complex head and neck regions where PET/CT imaging can present challenges. The second aim is to serve as an educational resource for oral radiologists. It provides insights into the interpretation of PET/CT images specifically in dento-maxillofacial conditions, helping them understand the unique imaging characteristics and potential diagnostic pitfalls associated with these lesions. This study highlights the importance of a multidisciplinary approach in ensuring accurate diagnosis of head and neck lesions.

MATERIALS AND METHODS

This study was conducted in accordance with ethical guidelines and received approval from the Kocaeli Health and Technology University, Non-invasive Clinical Research Ethics Committee (Project No: 2024-101) at 10.10.2024. The study protocol was reviewed and approved by the Institutional Review Board (IRB), ensuring compliance with ethical standards. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. All patient data were anonymized to maintain confidentiality.

Patient selection

This research was designed as a retrospective observational cross-sectional study. The study analyzed existing FDG-PET/CT, CT, and MRI images to compare metabolic activity (SUVmax values) in dentomaxillofacial conditions. The study was conducted and reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure transparent and standardized reporting of observational research [6]. A total of 463 images obtained from Kocaeli City Hospital, Department of Radiology were evaluated. The aim was to investigate dentomaxillofacial lesions, including bone defects, maxillary sinus diseases and inflammatory conditions, using FDG-PET/CT imaging which were not only specifically acquired for head and neck pathology but were evaluated for detection of hypermetabolism in the area. Between January 2022 and March 2024, a total of 2,843 FDG-PET/CT scans of the head and neck region were reviewed. Each case was screened systematically according to predefined inclusion and exclusion criteria. Inclusion criteria were; availability of pre-treatment FDG-PET/CT imaging of the head and neck region, accompanying diagnostic CT or MRI of the same region performed within four weeks of the PET/CT scan, histopathological confirmation of diagnosis for all malignant lesions, images of high diagnostic quality without severe artifacts and patients who provided informed consent for the scientific use of their imaging data. Exclusion criteria were; prior surgery, chemotherapy, or radiotherapy before the imaging date, missing or incomplete correlation studies (CT or MRI not performed within four weeks), motion-degraded or low-resolution scans unsuitable for accurate SUV measurement, lack of consent for scientific use of data. Following these criteria, 100 patients were included in the study. Patients were categorized into five diagnostic groups based on radiological and clinical interpretation: Dental artifacts (n=19), Common dental and periodontal infections (n=23), Maxillary sinus pathologies (n=21), Temporomandibular joint (TMJ) pathologies (n=19), Malignant dentomaxillofacial lesions (n=18, control group). This study included all eligible cases identified from the institutional imaging archive. A non-probability purposive sampling strategy was applied.

All imaging data were fully anonymized before analysis, with identifying patient information removed from Digital Imaging and Communications in Medicine (DICOM) headers. The images were reviewed blinded to patient names, demographic details, and clinical history beyond basic inclusion criteria. Group categorization was based on imaging findings.

Imaging protocols

Fasting patients with serum blood glucose levels below 12 mmol/L were administered a standardized dose of 18F-FDG in accordance with the protocol of Kocaeli City Hospital. Following injection, patients rested supine for one hour in a warm environment. FDG-PET/CT, CT, and MRI images were evaluated in an optimal environment. Scans were conducted using integrated PET/CT systems. FDG-PET/CT scans were analyzed on a GE Healthcare Workstation, enabling the viewing of CT, MRI, and PET/CT images in overlay mode across three planes simultaneously. PET/CT scans were evaluated for maximum standardized uptake values (SUVmax) to measure metabolic activity. Abnormally increased FDG uptake in the dentomaxillofacial region was identified and recorded. The SUVmax within regions of interest was assessed using a volume-of-interest tool with a 42% SUVmax threshold, with manual adjustments for individual lesions when necessary. The Revolution™ EVO/Optima™ CT660 CT Scanner (GE Healthcare Japan Corporation, Tokyo, Japan) was used for CT scans, and the SIGNA™ Pioneer (GE Medical Systems, Waukesha, USA) was used for

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MR imaging.

The primary outcome of this study was the SUVmax of fluorine-18-labeled FDG within each identified dento-maxillofacial lesion. Secondary outcomes included qualitative imaging characteristics (lesion location, structural involvement, presence of dental artifacts) and descriptive analysis of patient demographics (age, sex, and diagnostic category). Maxillary sinus pathologies in this study included mucosal thickening, retention cysts, and inflammatory polyps, while TMJ pathologies included degenerative and structural changes such as condylar flattening, osteophyte formation, and joint space narrowing. Cases classified as benign showed no radiological evidence of aggressive behavior, bone destruction, or suspicious enhancement and were confirmed by clinical records when accessible. Inclusion of malignant or suspicious lesions in this study required histopathological confirmation.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). Prior to hypothesis testing, the normality of SUVmax distributions was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated with Levene's test. As SUVmax values were not normally distributed, non-parametric tests were applied. The Kruskal–Wallis H test was used to compare SUVmax values among the five diagnostic groups. For pairwise group comparisons, Mann–Whitney U tests were conducted with Bonferroni correction to control for multiple comparisons. Quantitative variables are reported as mean ± standard deviation (SD) and range (min–max); categorical variables are presented as counts and percentages. Quantitative variables (e.g., SUVmax values, age) were summarized using mean ± standard deviation (SD), minimum and maximum values, and medians with interquartile ranges (IQRs) when appropriate. Qualitative variables (e.g., gender, diagnostic group) were summarized as counts and percentages. Receiver Operating Characteristic (ROC) curve analysis was performed to assess the diagnostic performance of SUVmax in differentiating malignant lesions from benign conditions. The optimal cut-off value was determined using the Youden index, and the area under the curve (AUC), sensitivity, and specificity were calculated. Statistical significance was defined as $p<0.05$, and exact p-values are reported in all tables.

RESULTS

Demographic analysis

A total of 100 patients were included in the study. The mean age of participants varied across groups, with the Malignant Lesions group presenting the highest average age at 59.3 years (SD: 7.09; range: 47–74 years). This was followed by the Maxillary Sinus Pathologies group, which had a mean age of 57.8 years (SD: 9.56; range: 34–72 years). Participants in the Periodontal Infections group had a mean age of 51.95 years (SD: 10.65; range: 32–68 years), while the Temporomandibular Joint (TMJ) Pathologies and Dental Artifacts groups had slightly younger averages of 50.95 years (SD: 12.66; range: 28–77 years) and 49.7 years (SD: 9.70; range: 32–67 years), respectively (Table 1).

Regarding gender distribution, the Dental Artifacts group included 11 females and 8 males, showing a slight female predominance. The Periodontal Infections group consisted of 9 females and 11 males, while the Maxillary Sinus Pathologies group had a nearly balanced distribution of 9 females and 12 males. The TMJ Pathologies group also showed a similar distribution with 10 females and 9 males. In contrast, the Malignant Lesions group had a marked male predominance with 13 males and 5 females (Table 1).

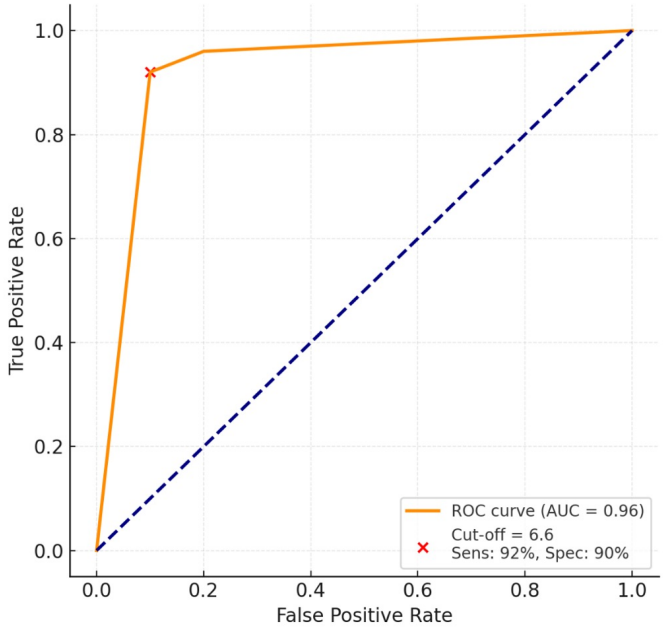

Figure 1. Receiver Operating Characteristic (ROC) curve of SUVmax in differentiating malignant lesions from benign dento-maxillofacial pathologies.

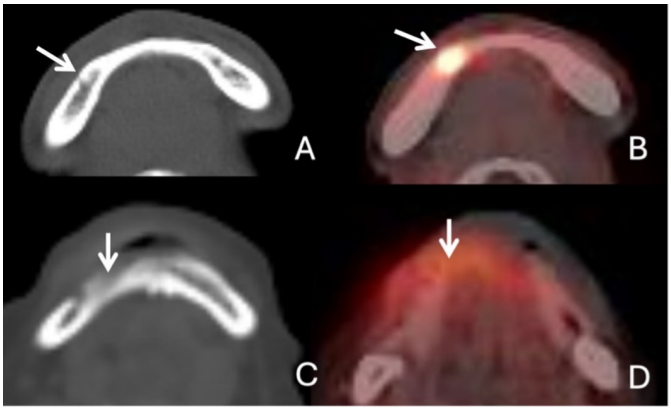

Figure 2. Axial CT section of an apical osteitis lesion in the anterior mandible (A) was revealed high FDG uptake (B). Note that bone socket after the extraction of right mandibular canine (C) also revealed high FDG uptake (D).

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Table 1. Demographic features of the groups.

Group	Mean Age	SD (Age)	Age Range	Female (n)	Male (n)
Dental Artifacts	49.7	9.70	32 -- 67	11	8
Periodontal Infections	51.95	10.65	32 -- 68	9	11
Maxillary Sinus Pathologies	57.8	9.56	34 -- 72	9	12
Temporomandibular Joint Pathologies	50.95	12.66	28 -- 77	10	9
Malignant Lesions (Control)	59.3	7.09	47 -- 74	5	13

Table 2. Distribution of SUVmax values according to diagnostic group.

Diagnostic Group	Mean ± SD	Minimum	Maximum
Dental Artifacts	2.5 ± 0.7	1.4	3.9
Periodontal Infections	3.5 ± 0.8	2.1	5.2
Maxillary Sinus Pathologies	4.2 ± 1.0	2.7	6.1
Temporomandibular Joint Pathologies	2.0 ± 0.6	1.0	3.1
Malignant Lesions (Control)	12.5 ± 3.0	7.9	18.1

Table 3. Pairwise comparisons of SUVmax amongst the diagnostic groups and malignant lesions.

Comparison Group	Test Used	Adjusted p-value (Bonferroni)
Dental Artifacts vs. Malignant Lesions	Mann-Whitney U	p = 0.00000128
Periodontal Infections vs. Malignant Lesions	Mann-Whitney U	p = 0.00000285
Maxillary Sinus Pathologies vs. Malignant Lesions	Mann-Whitney U	p = 0.00000323
TMJ Pathologies vs. Malignant Lesions	Mann-Whitney U	p = 0.00000156

Table 4. Normal FDG uptake in oral and maxillofacial PET/CT imaging: Regions and Reasons.

Region	FDG Uptake Characteristics
Waldeyer's ring	Presence of lymphatic tissue
Nasopharyngeal tonsils	Lymphatic tissue activity
Major salivary glands	Accumulation and secretion with saliva, potential asymmetrical uptake due to pooling, which can mimic malignancy
Muscle (scalene, sternocleidomastoid, pterygoid, etc.)	Increased metabolic activity, often associated with muscle use or tension
Brown fat	Function of producing thermal energy, requiring CT correlation

Table 2 presents the descriptive statistics for standardized uptake values (SUVmax) across the five diagnostic groups. The Malignant Lesions group demonstrated the highest metabolic activity, with a mean SUVmax of 12.5 ± 3.0 (range: 7.9–18.1), which was significantly greater than all other groups ($p<0.001$ for all comparisons). This finding aligns with the high glycolytic activity commonly observed in malignant tumors. Among the non-malignant conditions, the Maxillary Sinus Pathologies group exhibited the highest mean SUVmax, measured at 4.2 ± 1.0 (range: 2.7–6.1). Although elevated, these values were still markedly lower than those observed in malignant lesions, indicating limited but notable metabolic activity—likely due to inflammatory or reactive changes. The Periodontal Infections group followed, with a mean SUVmax of 3.5 ± 0.8 (range: 2.1–5.2), consistent with the metabolic demand associated with acute or active dental infections. Dental Artifacts and Temporomandibular Joint (TMJ) Pathologies groups exhibited the lowest SUVmax values, with means of 2.5 ± 0.7 and 2.0 ± 0.6, respectively. These low values suggest minimal FDG uptake, consistent with the non-inflammatory, mechanical, or artifact-related nature of these findings. The TMJ group in particular showed the lowest overall metabolic activity (range: 1.0–3.1), reinforcing that structural joint changes are not typically associated with hypermetabolism (Table 2).

All diagnostic groups demonstrated significantly lower SUVmax values compared to the malignant lesion group ($p<0.001$ in all cases) (Supplementary Table). Among the non-malignant conditions, maxillary sinus pathologies exhibited the highest mean SUVmax, yet remained significantly lower than malignant lesions. TMJ pathologies and dental artifacts showed the lowest SUVmax values, indicating minimal metabolic activity in these structural or mechanical conditions (Table 3). ROC analysis showed that SUVmax had excellent discriminative ability for differentiating malignant lesions from benign conditions (AUC = 0.96, 95% CI: 0.91–0.99, $p<0.001$). A cut-off value of 6.6 provided a sensitivity of 92% and specificity of 90% (Figure 1).

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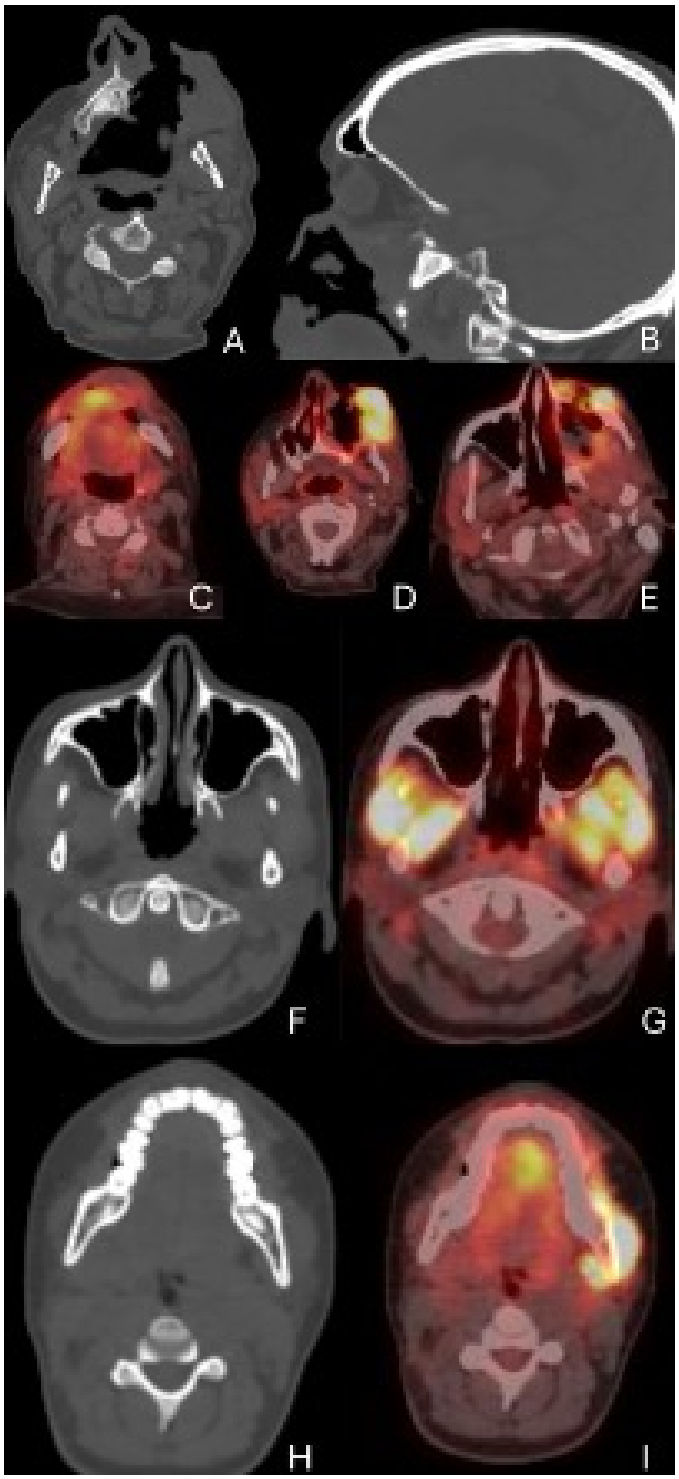

Figure 3. A 66-year-old male with sinonasal carcinoma invading the maxilla and maxillary sinus region (A, B), demonstrating high metabolic activity on FDG-PET/CT imaging (C, D, E). A 19-year-old female presenting with increased metabolic activity observed in the masseter and medial pterygoid muscles bilaterally, attributed to temporomandibular overuse, as depicted on PET/CT imaging. The patient had no previous TMJ pathology diagnosis (F, G, H, I).

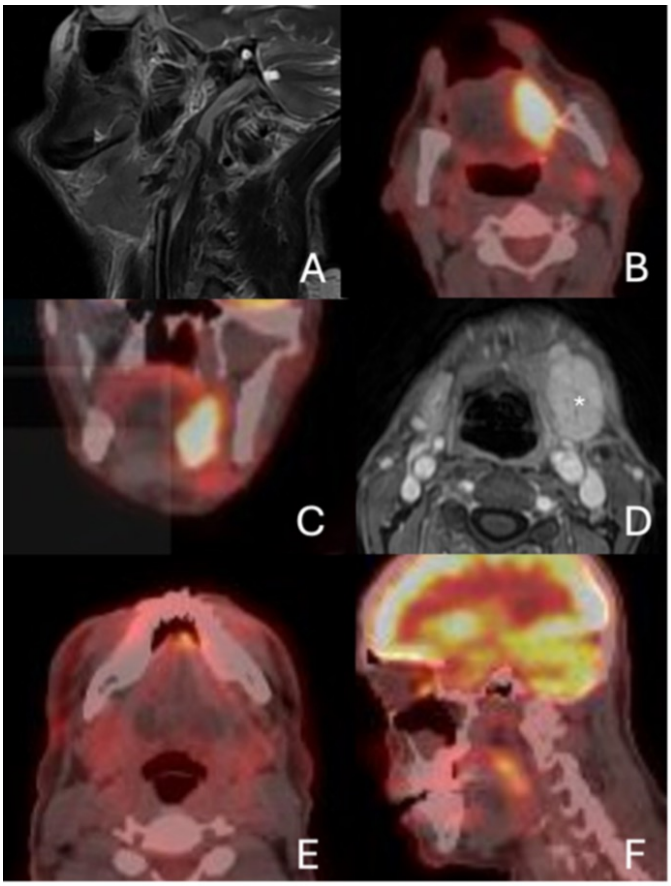

Figure 4. A 70-year-old male diagnosed with squamous cell carcinoma (SCC) of the tongue, characterized by a contrast-enhancing lesion measuring 20x14x35 mm in the left posterior region (A). PET/CT imaging showed a maximum standardized uptake value (SUVmax) of 20.75 within the lesion (B, C). Additionally, enlargement of the left submandibular gland was noted (D). A 53-year-old male diagnosed with SCC of the anterior tongue as the primary lesion. PET/CT imaging revealed mild FDG uptake in 11 mm lymph nodes in the left submandibular and upper jugular regions, indicative of metastasis (E, F).

DISCUSSION

This study evaluated the role of FDG-PET/CT imaging and SUVmax measurements in differentiating malignant from benign oral and maxillofacial pathologies, using histopathological confirmation for all malignant lesions and imaging-based criteria for benign diagnoses. The results demonstrated that SUVmax were significantly higher in malignant lesions than in all benign groups, supporting previous reports [8-14]. Representative images for each group are presented in Figures 2-5. Figures illustrate the wide spectrum of SUVmax observed in both malignant and benign dento-maxillofacial conditions.

Malignant lesions consistently demonstrated high FDG uptake (Figure 4), and this showed their high metabolic activity, while benign findings—including inflammatory maxillary sinus disease, periodontal infections, and degenerative temporomandibular joint changes—showed variable but occasionally lower SUVmax. Benign lesions with inflammatory or reparative activity can mimic malignancy on PET/CT. Misinterpretation of these findings may lead to unnecessary biopsies, treatment delays, or unwarranted anxiety. This study also highlights that low SUVmax do not always rule out malignancy. Some malignant tumors, especially low-grade, early-stage, or histologically less metabolically active cancers can demonstrate SUVmax overlapping with benign conditions

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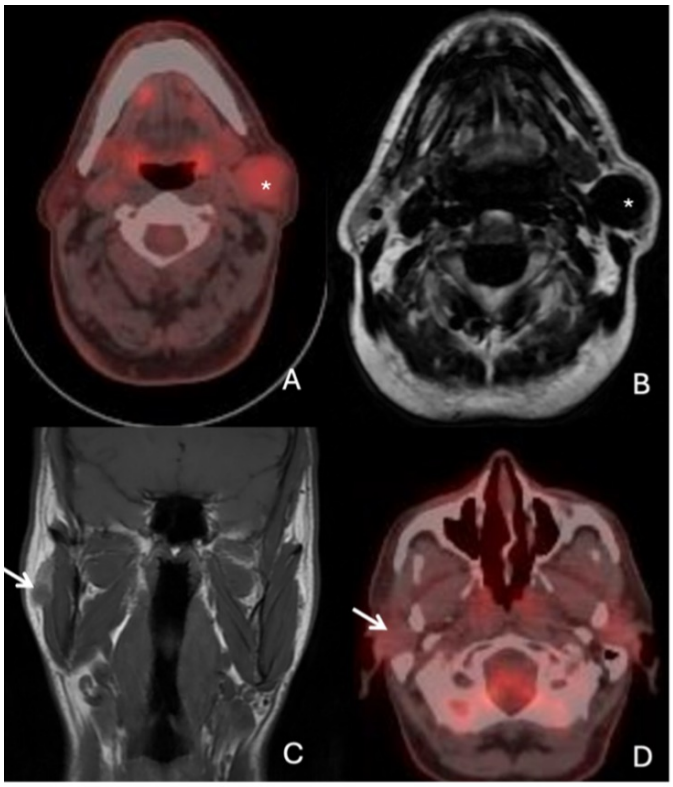

Figure 5. A 60-year-old female diagnosed with adenocystic carcinoma of the left parotid gland. Imaging revealed a solid lesion measuring 27x25x40 mm in the posterior inferior part of the gland (A), characterized by hypointense lesion on axial LAVA Flex MR image (B). A 45-year-old male initially diagnosed with a pleomorphic adenoma of the right parotid gland based on imaging findings showing dimensions of 12.5 x 13.5 x 13 mm with mild hypointense lesion on coronal Fast Spin Echo T1-weighted images (C). PET/CT imaging, however, revealed no malignant activity within the lesion (D).

(Figure 5). Such findings present a critical limitation of relying only on SUVmax thresholds for diagnosis. Careful interpretation of imaging context, lesion morphology, and histopathological confirmation remains essential to avoid misdiagnosis or delayed treatment.

FDG-PET/CT is a powerful diagnostic tool but must be interpreted with caution in the head and neck due to physiological uptake. As summarized in Table 4, normal uptake in Waldeyer's ring, salivary glands, muscles, and brown fat may mimic malignancy [1,3,5,7]. Co-registration with CT enables precise localization of FDG activity, helping distinguish normal physiology from pathology (Table 4).

Our findings demonstrate that malignant lesions displayed higher SUVmax than benign conditions ($p<0.01$). Prior studies reporting SUVmax thresholds of 6.0–12.0 for head and neck squamous cell carcinoma and other malignancies [8-13]. The ROC analysis of this present study revealed a cut-off of 6.6, which is a correlated finding with Schwaninger et al. [8]. Schwaninger et al. [8] reported FDG accumulation in acute periapical inflammation, though they found no correlation with periapical index scores. Ito et al. [9] demonstrated the value of PET/CT in assessing periodontal disease and predicting complications such as osteonecrosis. Yamashiro et al. [10] similarly noted that FDG uptake was present in acute infections but absent in chronic apical infections, supporting PET/CT as a screening tool for high-risk infections. Our results are consistent with these findings, as no FDG uptake was observed in chronic periodontal disease cases in this study. Chronic maxillary sinusitis typically demonstrates minimal or absent hypermetabolic activity on PET/CT, whereas sinonasal carcinoma shows markedly increased FDG uptake (Figure 3). These imaging patterns correlate with CT findings; sinonasal carcinoma often exhibits ill-defined, irregular borders and invasive features, helping radiologists differentiate malignant tumors from inflammatory or benign sinonasal conditions [12,13].

Identifying infection foci before cancer therapy is critical, especially in patients scheduled for head and neck radiotherapy or chemotherapy. Chronic lesions may appear inactive on PET/CT but can exacerbate during treatment, leading to osteonecrosis or delayed healing [9,13,14]. Schuurhuis et al. [15] emphasized that severe periodontal disease increases the risk of post-radiotherapy complications. Early detection of hypermetabolic lesions on PET/CT can guide referral to oral care specialists [10,15,16].

This study identified dental prosthetic artifacts affecting FDG-PET/CT quality, emphasizing the need to remove dentures before scanning. PET/CT also revealed the heterogeneity of FDG uptake in malignancies; SUVmax variability across tumor types and stages reflects the biological diversity of cancers [17,18]. Prior studies indicate SUVmax can predict disease progression and survival [17,19], which is valuable as a biomarker.

Limitations

This study is limited by its retrospective design, single-center scope, and small sample size. Intraoral examinations, which are critical for comprehensive cancer treatment planning, were not available. Additionally, SUVmax variability can be influenced by patient preparation, imaging protocols, and FDG uptake timing; standardizing these parameters could improve reproducibility. Larger, prospective studies are needed to validate these findings and further characterize FDG uptake in diverse dentomaxillofacial pathologies.

CONCLUSION

The objectives of this study were to evaluate the distribution and metabolic activity of dento-maxillofacial lesions and potential inflammatory pathologies on FDG-PET/CT scans, and to compare these findings on CT and MR images. This study indicated that a significant proportion of radiologically detected periapical lesions, areas of marginal periodontal bone loss, and other possible inflammatory jaw pathologies did not exhibit increased metabolic activity or signs of acute inflammation on FDG-PET/CT, regardless of their radiological extent or location. However, the study did identify various cases

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that could be valuable for future research and radiologic assessments. These findings show the necessity for further studies to evaluate a broader range of images, potentially improving our understanding of the metabolic activity in various dento-maxillofacial pathologies.

Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Committee Approval: This study was approved by Kocaeli Health and Technology University Non-Invasive Clinical Research Ethics Committee with project no: 2024-101 at 10.01.2024.

Informed Consent: In this study, only patients with present informed consent were included.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The authors declare that there are no conflicts of interest regarding this study.

Author Contributions: Concept: MSM, MÖ; Methodology: MÖ, MSM; Data Collection: MÖ; Data Analysis: MÖ; Writing: MSM; Review & Editing: MÖ, MSM.

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