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Relationship Between Nutrient Canals and Trabecular Bone Sclerosis in Cyst-Affected Jaws: A CBCT Study

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Research Article

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ABSTRACT

Objectives: This study aimed to investigate the relationship between the presence of nutrient canals and potential trabecular bone changes in jaws with or without cysts, using two different classification methods.
Materials and Methods: CBCT images from 60 patients with unilateral jaw cysts located in either the maxilla or mandible were reviewed retrospectively. Cyst-affected sides with or without nutrient canals were grouped and compared to all unaffected sides combined. Trabecular bone quality was assessed both qualitatively (visual trabecular pattern classification) and quantitatively (modified Lekholm and Zarb classification based on HU ranges). Fisher's Exact and Fisher-Freeman-Halton tests were used to compare frequencies between groups. Intra-observer reliability was assessed using Kappa statistics. Significance was set at $p < 0.05$.
Results: Nutrient canals were significantly associated with sclerotic trabecular bone patterns in cyst-affected regions ($p = 0.001$), with nutrient canals more frequent in areas of "average" or "above-average" trabecular density. Nutrient canals also showed a significant association with the highest bone density category (Q1) in both cystic ($p < 0.001$) and non-cystic regions ($p = 0.003$). A significant association was observed between qualitative and quantitative classifications ($p < 0.001$). Intra-observer reliability was moderate for visual trabecular assessments and high for the quantitative classification.
Conclusions: Sclerotic changes in the trabecular bone around jaw cysts are closely associated with occurrence of nutrient canals, potentially reflecting compensatory vascular adaptation. Understanding this relationship and clearly documenting nutrient canals in CBCT reports can provide clinicians with valuable information to optimize surgical planning and minimize potential complications associated with jaw cysts. The modified Lekholm and Zarb classification may serve as a reliable alternative to visual methods for assessing bone quality on CBCT images.

Keywords: Neurovascular canals, radicular cyst, dentigerous cyst, trabecular sclerosis

Çene Kistleri Çevresindeki Trabeküler Kemik Değişiklikleri ile Besin Kanalı Varlığı Arasındaki İlişki: CBCT Çalışması

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ÖZ

Amaç: Bu çalışma, iki farklı sınıflandırma yöntemi kullanarak, kistli veya kistsiz çenelerde besin kanallarının varlığı ile potansiyel trabeküler kemik değişiklikleri arasındaki ilişkiyi araştırmayı amaçlamıştır.
Gereç ve Yöntemler: Maksilla veya mandibulada tek taraflı çene kistleri bulunan 60 hastanın CBCT görüntüleri retrospektif olarak incelendi. Kistten etkilenen, beslenme kanalı olan ve olmayan taraflar gruplandırıldı ve etkilenmemiş tüm taraflarla karşılaştırıldı. Trabeküler kemik kalitesi hem kalitatif (görsel trabeküler patern sınıflandırması) hem de kantitatif (HU aralıklarına dayalı modifiye Lekholm ve Zarb sınıflandırması) olarak değerlendirildi. Gruplar arasındaki sıklıkları karşılaştırmak için Fisher'ın Kesin Testi ve Fisher-Freeman-Halton testi kullanıldı. Gözlemci içi güvenilirlik Kappa istatistiği kullanılarak değerlendirildi. Anlamlılık düzeyi $p < 0{,}05$ olarak belirlendi.
Bulgular: Besin kanalları, kistten etkilenen bölgelerde sklerotik trabeküler kemik paternleriyle anlamlı bir şekilde ilişkiliydi ($p = 0{,}001$), besin kanalları "ortalama" veya "ortalamanın üzerinde" trabeküler yoğunluğa sahip bölgelerde daha sık görülmekteydi. Besin kanalları da hem kistik ($p < 0{,}001$) hem de kistik olmayan bölgelerde ($p = 0{,}003$) en yüksek kemik yoğunluğu kategorisi (Q1) ile önemli bir ilişki gösterdi. Kalitatif ve kantitatif sınıflandırmalar arasında anlamlı bir ilişki gözlemlenmiştir ($p < 0{,}001$). Görsel trabeküler değerlendirmelerde gözlemci içi güvenilirlik orta düzeyde, kantitatif sınıflandırmada ise yüksek düzeydeydi.
Sonuçlar: Çene kistlerinin çevresindeki trabeküler kemikteki sklerotik değişiklikler, besin kanallarının oluşumuyla yakından ilişkilidir ve bu durum, telafi edici vasküler adaptasyonu yansıtıyor olabilir. Bu ilişkiyi anlamak ve besin kanallarını CBCT raporlarında açıkça belgelemek, çene kistleriyle ilişkili cerrahi planlamalarda potansiyel komplikasyonları en aza indirmek için klinisyenlere değerli bilgiler sağlayabilir. Modifiye Lekholm ve Zarb sınıflandırması, CBCT görüntülerinde, kemik kalitesini değerlendirmek için görsel yöntemlere güvenilir bir alternatif olabilir.

Anahtar Kelimeler: Nörovasküler kanallar, radiküler kist, dentigeröz kist, trabeküler sklerozis

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Introduction

Nutrient canals were first described by Hirschfeld in 1923.[1] These structures, most commonly observed in the anterior mandibular region, appear as uniformly wide, vertically oriented radiolucent lines on periapical radiographs. They transmit neurovascular bundles that supply the teeth, gingiva, and interdental spaces.[2,3]

Clinically, nutrient canals are important because trauma to their neurovascular contents during mandibular surgery can lead to complications such as postoperative paresthesia and bleeding. Therefore, their identification and documentation in cone-beam computed tomography (CBCT) reports are essential to minimize surgical risks and improve patient outcomes.[4]

Among the anatomic structures visible on radiographs, nutrient canals are particularly puzzling, both in terms of their presence and absence.[5] It is still debated whether they develop over time or become more prominent due to the enlargement of pre-existing channels.[2,6] Studies using intraoral radiographs have reported an increased prevalence of nutrient canals in patients with systemic conditions such as hypertension and diabetes mellitus, as well as in local inflammatory conditions, including periodontitis. These conditions can affect bone metabolism and vascular dynamics, potentially altering trabecular bone architecture.[7-9] Our observations from CBCT imaging, along with findings from our pilot study (in press), suggest that while nutrient canals in the anterior jaw segments likely represent normal anatomy, their presence in the posterior jaw regions may be linked to pathological conditions, such as jaw cysts.

Previous research using conventional radiographs has reported associations between nutrient canals and specific trabecular bone patterns.[2,6,10,11] For example, studies using periapical radiographs have shown that patients with smaller trabecular spaces tend to exhibit a higher prevalence of nutrient canals.[10,11] These findings suggest that sclerotic changes in trabecular bone are associated with an increased occurrence of nutrient canals, potentially indicating regions with altered vascular demand. If confirmed in the context of jaw cysts, this relationship could have important clinical implications for reducing risks of complications such as nerve injury, bleeding, and delayed healing.

Jaw cysts may stimulate or coincide with increased bone sclerosis in surrounding trabecular bone as a reactive or reparative process. This sclerosis may then be associated with an increased presence or visibility of nutrient canals, possibly due to increased vascular demand or remodeling-induced changes in vascular channels. Therefore, jaw cysts act as a pathological trigger or modifier that affects local bone quality and vascular structures, potentially amplifying or highlighting the association between nutrient canals and sclerotic trabecular bone.

Several classification systems have been developed to assess bone quality based on qualitative and quantitative criteria.[12] The Lekholm and Zarb classification, widely used in implant dentistry, is a qualitative system that categorizes bone according to the relative proportions of cortical and trabecular components seen on radiographs.[13] More recent studies utilizing computed tomography (CT) have proposed modified versions of this classification by integrating Hounsfield Unit (HU) measurements for a more objective assessment of bone density.[14,15] With the growing use of CBCT in dental diagnostics, there is a need to validate these modified classifications for assessing bone changes associated with pathological lesions. To date, no study has applied the modified Lekholm and Zarb classification to CBCT images in the setting of jaw cysts.

A better understanding of the relationship between nutrient canals and trabecular bone alterations in cyst-affected jaw regions could improve diagnostic interpretation and surgical planning, particularly in identifying areas of increased vascularity or bone sclerosis. Considering the potential vascular and trabecular adaptations in response to cystic pathology, this study aimed to investigate whether the presence of nutrient canals is associated with sclerotic changes in trabecular bone in cyst-affected jaw regions. Additionally, the study sought to evaluate the correlation between qualitative visual assessments of trabecular bone patterns and quantitative, HU-based modified Lekholm and Zarb classification categorized into bone quality classes.

We hypothesized that trabecular bone surrounding jaw cysts exhibits relative sclerosis compared to contralateral healthy regions, and that this sclerotic change is associated with occurrence of nutrient canals. Furthermore, we propose that the modified quantitative classification system correlates with visual assessments and could serve as an objective alternative.

Materials and Methods

Study Design

This observational study was approved by the Institutional Review Board of Sivas Cumhuriyet University (No. 2023-06/09) and conducted in accordance with the principles of the Declaration of Helsinki. The study was conducted at the Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Sivas Cumhuriyet University between July to December 2023. CBCT scans from patients with clinically or histologically confirmed jaw cysts were reviewed retrospectively. The study was conducted using data obtained with prior informed patient consent.

Participants

Sixty patients aged 14 to 50 years were included if they were periodontally healthy or exhibited mild, symmetrical bone loss limited to the cervical third of the tooth roots on both sides of the same jaw, and if the cystic lesion was localized unilaterally in a single jaw (either maxilla or mandible). Exclusion criteria included the presence of additional pathology near the cyst on the affected side, any lesion on the contralateral (unaffected) side, asymmetric tooth loss, systemic conditions affecting bone metabolism (*e.g.*, diabetes mellitus, hypertension, rickets, hematological disorders), a history of radiotherapy or chemotherapy, prior surgical interventions, advanced periodontitis or significant bone loss, and CBCT scans with motion or metal artifacts that impaired reliable evaluation of the regions of interest (ROIs).

CBCT Image Acquisition

Archived CBCT images obtained using a Planmeca ProFace ProMax 3D Mid device (Planmeca Oy, Finland) were included in this study. Image acquisition parameters were as follows: a voxel size ranging from 0.15 to 0.2 mm, field of view (FOV) dimensions of 8 x 5 cm to 10 x 16 cm, tube voltage set at 90 kVP, tube current of 8 mA to 10 mA.

Sample Size

The required sample size was determined using G*Power version 3.1.9.6. Based on mean HU values from a pilot study, a minimum of 17 patients per group was needed to achieve a statistical power of 95% (1-β) and an effect size (d) of 1.314, with a significance level of 5% ($\alpha = 0.05$). From an initial pool of 230 CBCT scans reviewed by a dentomaxillofacial radiology resident with three years of clinical experience, 60 scans meeting the inclusion criteria were selected for analysis. Each scan included one cyst-affected side and one unaffected contralateral side, resulting in 120 regions evaluated. To assess intra-observer reliability, 15 randomly selected CBCT images (25% of the sample) were re-evaluated after a two-week interval.

Lesion Identification and Classification

Radiolucent lesions around non-vital teeth with well-defined cortical borders and exceeding 2 cm in diameter were classified as radicular cysts.[16,17] Radiolucent lesions associated with the crown of unerupted teeth, originating from the cemento-enamel junction and with a follicular space greater than 5 mm, were identified as dentigerous cysts.[16] Cystic lesions located inferior to the mandibular canal were categorized as non-odontogenic cysts.[18]

Region of Interest (ROI) Selection

The ROIs (1.20 mm × 1.20 mm) were selected from the trabecular bone around the nutrient canal in the presence of a canal, and from the trabecular bone adjacent to the cyst in the absence of a canal. For comparison, an equal number of ROIs were selected from the trabecular bone in the contralateral tooth regions corresponding to the cyst areas (Figure 1). To investigate the relationship between nutrient canals and trabecular structures, CBCT scans from 60 patients with unilateral jaw cysts (in either the maxilla or mandible) were evaluated. For each patient, only the affected jaw (maxilla or mandible) was included in the analysis. Within that jaw, the cyst-affected side was compared to the contralateral, unaffected side (Figure 2 and 3). A total of 120 jaw sides (60 affected and 60 contralateral) were assessed. The presence of nutrient canals was evaluated both qualitatively and quantitatively using two distinct trabecular bone structure classifications.

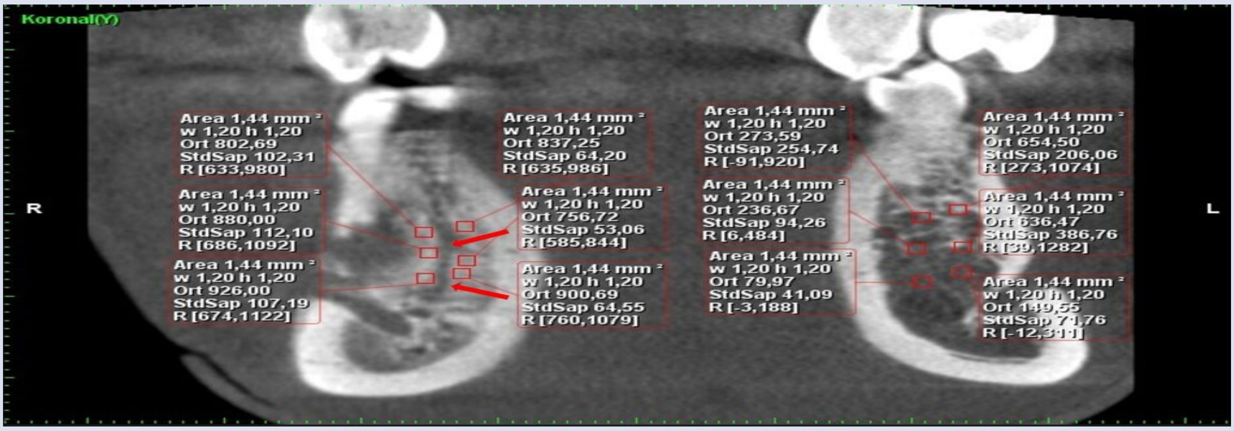

Figure 1. Selection of regions of interest (ROIs) from the area surrounding the nutrient canal (red arrows) adjacent to the cyst and from the corresponding contralateral dental region without a cyst.

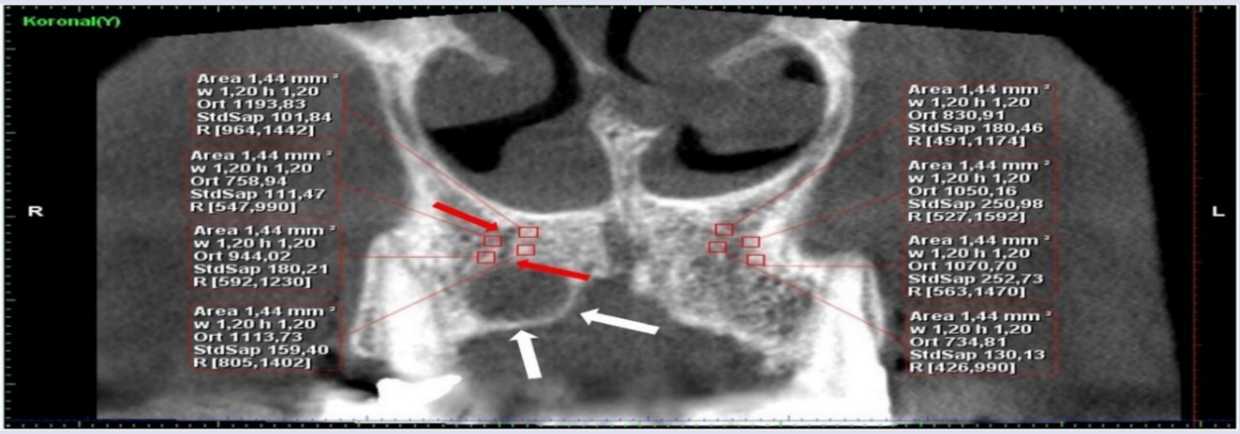

Figure 2. Maxillary regions with both cysts (white arrows) and nutrient canals (red arrows), and corresponding contralateral regions without cysts or nutrient canals.

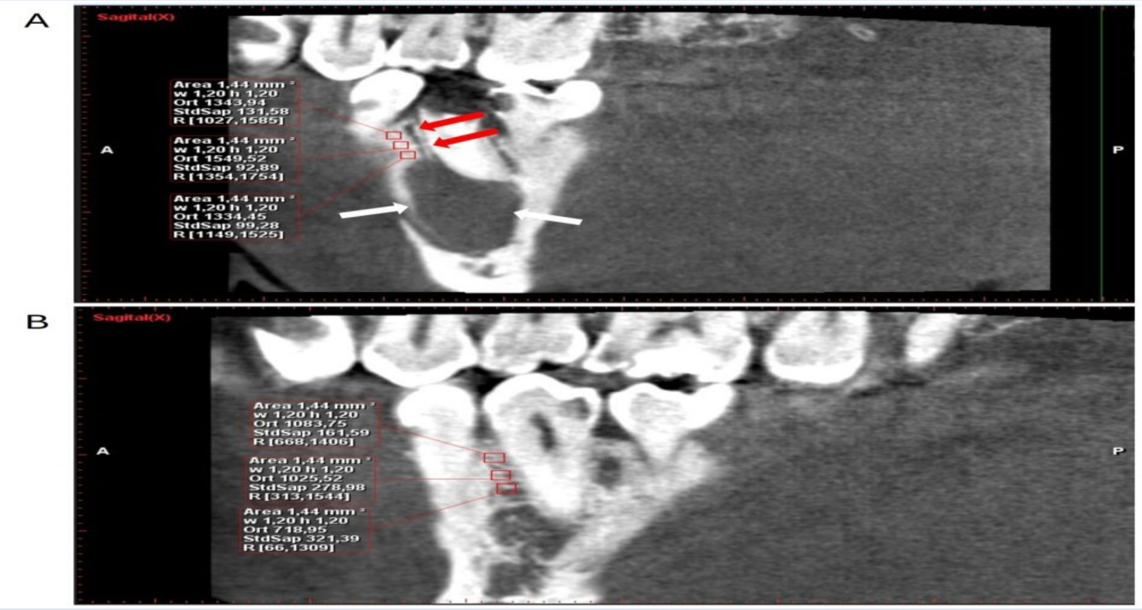

Figure 3. Mandibular regions with both cysts (white arrows) and nutrient canals (A, red arrows), and corresponding contralateral regions without cysts or nutrient canals (B).

Bone Quality Classification

Bone quality was quantitatively classified as Q1, Q2-3, and Q4 based on mean HU values according to the modified Lekholm and Zarb classification as proposed by Norton and Gamble (Table 1).[15] Hounsfield Unit (HU) measurements obtained from CBCT images were categorized into bone quality classes based on the modified Lekholm and Zarb classification system. Raw HU values were not analyzed as continuous variables but grouped into categorical classes for all subsequent analyses. For qualitative assessment, bone quality was categorized using a visual evaluation of trabecular patterns on CBCT images as below average, average, or above average (Table 2).[6] The correlation between these two classification methods was analyzed to assess the clinical utility of the HU-based modified Lekholm and Zarb classification.

Statistical Analysis

All statistical analyses were conducted using SPSS Version 23 (IBM Corp., Armonk, NY). The normality of data distribution was checked using the Shapiro-Wilk test. As all variables included in the final analyses were categorical, parametric tests for continuous data were not applied. Categorical variables, including nutrient canal presence and trabecular bone pattern classifications, were analyzed using Fisher's Exact test, Fisher-Freeman-Halton test for larger contingency tables, and Yates' continuity correction for 2 x 2 tables, as appropriate. Multiple comparisons were adjusted with the Bonferroni-corrected Z-test. The association between the trabecular pattern classification and the modified Lekholm and Zarb bone quality categories was further evaluated using Pearson's Chi-square test, and the strength of the relationship was examined using Cramer's V coefficient. Intra-observer reliability was assessed using Intraclass Correlation Coefficients (ICCs) and Cohen's Kappa statistics. Kappa values were interpreted as follows: 0.41–0.60 indicating moderate agreement, 0.61–0.80 substantial agreement, and values above 0.80 indicating excellent agreement. The results are presented as frequencies (percentages). The significance level was set at $p < 0.05$.

Table 1. Bone density classification categories based on Hounsfield Unit (HU) ranges according to the modified Lekholm and Zarb system

Q1	>850
Q2-Q3	850-500
Q4	500-0
Q5	<0

This table presents the HU thresholds used to categorize bone quality into Q1, Q2-Q3, and Q4 classes for subsequent analyses.

Q1: Almost entire jaw is comprised of homogenous compact bone; Q2: A thick layer of compact bone surrounds a core of dense trabecular bone; Q3: A thin layer of cortical bone surrounds a core of dense trabecular bone; Q4: A thin layer of cortical bone surrounds a core of low-density trabecular bone.[15]

Table 2. Qualitative trabecular bone pattern classification based on visual CBCT assessment[6]

Above average	Increased radiopacity, narrowed medullary spaces
Average	Moderate radiopacity, medullary spaces of normal size and shape
Below average	Increased radiolucency, enlarged medullary spaces

Results

The mean age of the study population (n = 60) was 29.92 ± 10.17 years (range: 14–50). Of the patients, 43.3% were female, and 56.7% were male. The majority of the lesions were radicular cysts (56.7%), followed by dentigerous cysts (28.3%) and residual cysts (10%). Histopathological confirmation was available for 27 lesions (45%), while 33 lesions (55%) were diagnosed clinically and radiographically. For consistency, all lesions were collectively referred to as "jaw cysts." Lesions were distributed across different jaw regions: 26.7% in the anterior, 16.7% in the premolar, and 56.7% in the molar region.

Association Between Nutrient Canals and Trabecular Pattern

In cyst-affected jaw regions, a significant association was found between the presence of nutrient canals and the qualitative trabecular bone pattern classification (p = 0.001; Table 3). Nutrient canals were more frequently observed in areas exhibiting average or above-average trabecular density. Conversely, in healthy (non-cystic) jaw regions, although nutrient canal frequency increased with trabecular density, this association was not statistically significant (p = 0.065). Thus, a significant relationship between nutrient canals and sclerotic trabecular patterns was evident only in cyst-affected regions (Table 3).

Nutrient Canals and Modified Lekholm and Zarb Classification

A significant association was also observed between nutrient canal presence and bone quality as classified by the modified Lekholm and Zarb system in both cystic and non-cystic jaw regions. In cyst-affected regions, nutrient canals were significantly more common in bone classified as Q1 (most sclerotic) (p < 0.001; Table 4).

Similarly, in non-cystic jaw regions, nutrient canals were significantly associated with the Q1 classification (p = 0.003; Table 4). These findings suggest that nutrient canals are consistently associated with sclerotic trabecular bone, regardless of lesion presence.

Association Between Qualitative and Quantitative Classifications

A significant association was found between the qualitative trabecular pattern classification and the quantitative modified Lekholm and Zarb classification (p < 0.001). The strength of the correlation between the two classifications was assessed using Cramer’s V, yielding a value of 0.570, which indicates a moderate to strong association between the two classifications. Specifically, the "below-average" trabecular pattern was most frequently associated with the Q4 classification (65.7%). The "average" trabecular pattern aligned with the Q2-Q3 category (55%), and the "above-average" pattern with the Q1 classification (80%) (Table 5).

Observer Reliability

Intra-observer agreement was moderate for visual trabecular pattern assessment and high for the modified Lekholm and Zarb classification, indicating acceptable and excellent consistency, respectively, for both methods (Table 6).

Table 3. Association between nutrient canal presence and trabecular pattern classification in cyst-affected and unaffected jaw regions

Jaw cyst	Nutrient canal	Trabecular pattern classification			Total	Test statistics	p*
		Below average n (%)	Average n (%)	Above average n (%)			
Present	Yes	0 (0)^{b}	9 (69.2)^{a}	33 (80.5)^{a}	42 (70)	14.496	0.001
	No	6 (100)	4 (30.8)	8 (19.5)	18 (30)		
Absent	Yes	0 (0)	3 (10.7)	3 (25)	6 (10)	4.903	0.065
	No	20 (100)	25 (89.3)	9 (75)	54 (90)		

Data represent combined cyst-affected jaw regions (n = 60 sides) compared to all unaffected sides combined (n = 60 sides) from the same patients.

**Fisher-Freeman-Halton test; ^{a,b}There is no significant difference between groups with the same superscript letter.*

Above Average: Increased radiopacity, narrowed medullary spaces; Average: Moderate radiopacity, medullary spaces of normal size and shape; Below Average: Increased radiolucency, enlarged medullary spaces.[6]

Table 4. Association between nutrient canal presence and bone quality classified by the modified Lekholm and Zarb System in cyst-affected and unaffected jaw regions

Jaw cyst	Nutrient canal	Lekholm and Zarb classification			Total	Test statistics	p*
		Q1 n (%)	Q2-Q3 n (%)	Q4 n (%)			
Present	Yes	30 (90.9)^{a}	12 (57.1)^{b}	0 (0)^{c}	42 (70)	21.738	<0.001
	No	3 (9.1)	9 (42.9)	6 (100)	18 (30)		
Absent	Yes	4 (33.3)^{a}	2 (10.5)^{ab}	0 (0)^{b}	6 (10)	9.203	0.003
	No	8 (66.7)	17 (89.5)	29 (100)	54 (90)		

Bone quality categories are based on HU ranges. Comparisons were made between all cyst-affected sides pooled together and all unaffected sides combined.

**Fisher-Freeman-Halton test; ^{a,b}There is no significant difference between groups with the same superscript letter.*

Q1: Almost entire jaw is comprised of homogenous compact bone; Q2: A thick layer of compact bone surrounds a core of dense trabecular bone; Q3: A thin layer of cortical bone surrounds a core of dense trabecular bone; Q4: A thin layer of cortical bone surrounds a core of low-density trabecular bone.[15]

Table 5. Correlation between qualitative trabecular pattern and quantitative modified Lekholm and Zarb bone quality classification across all jaw regions

Trabecular pattern classification	Lekholm and Zarb classification			Total	Test statistics	p*	Cramer's V (p)
	Q1 n (%)	Q2-Q3 n (%)	Q4 n (%)				
Below average	0 (0)^{a}	3 (7.5)^{a}	23 (65.7)^{b}	26 (21.7)	78.044	<0.001	0.570 (<0.001)
Average	9 (20)^{a}	22 (55)^{b}	10 (28.6)^{ab}	41 (34.2)			
Above average	36 (80)^{a}	15 (37.5)^{b}	2 (5.7)^{c}	53 (44.2)			

*Frequencies (%) reflect the distribution of trabecular patterns within bone quality classes for both cyst-affected and unaffected jaw regions combined. *Pearson Chi-square test; $^{a-c}$There is no significant difference between groups with the same superscript letter. Q1: Almost entire jaw is comprised of homogenous compact bone; Q2: A thick layer of compact bone surrounds a core of dense trabecular bone; Q3: A thin layer of cortical bone surrounds a core of dense trabecular bone; Q4: A thin layer of cortical bone surrounds a core of low-density trabecular bone.[15]*

Above Average: Increased radiopacity, narrowed medullary spaces; Average: Moderate radiopacity, medullary spaces of normal size and shape; Below Average: Increased radiolucency, enlarged medullary spaces.[6]

Table 6. Intra-observer agreement for trabecular pattern and modified Lekholm and Zarb classification measurements

Measurement	Kappa	p
Trabecular pattern measurements around lesions	0.516	0.009
Trabecular pattern measurements in lesion-free contralateral jaws	0.786	<0.001
Modified Lekholm and Zarb measurements in study groups	1.000	<0.001

Discussion

No previous studies have directly investigated the association between nutrient canals and trabecular bone changes in jaw cysts, making direct comparisons challenging. However, findings from related studies on other conditions, such as periodontitis, support our results. These earlier studies, mostly based on periapical radiographs, found that nutrient canals are linked to smaller trabecular spaces and increased radiopacity, indicating denser bone.[2,6,10,11] For example, Ryder[11] observed nutrient canals more often in jaws with fine alveolar ridges and limited trabecular spaces. Patel and Wuehrmann[10] reported that nutrient canals were associated with small, non-horizontally arranged trabecular spaces based on periapical radiographs. Similarly, Kishi et al.[6] classified trabecular bone visually and found that nutrient canals were more prevalent in patients with above-average bone density and reduced trabecular spacing, likely reflecting sclerotic changes due to periodontitis. In a 2013 study, Pandarinath[2] also reported a significant association between nutrient canals and denser trabecular bone pattern in patients with periodontitis ($p < 0.001$).

The Lekholm and Zarb classification is considered the "gold standard" method for preoperative bone quality assessment, based on the ratio of cortical to trabecular bone seen on radiographs.[13,19] Some authors have modified this classification to improve reproducibility, adding new classes and subclasses to the original classification.[13,20] Others have introduced quantitative ranges for the four classes of the Lekholm and Zarb classification using CT-based HU values.[14,15] In those studies, Norton and Gamble,[15] as well as De Oliveira et al.[14] highlighted the difficulty in distinguishing between Q2 and Q3 bone classes through subjective visual evaluation or quantitative bone density measurements.

In CT imaging, clinicians commonly use the Hounsfield scale, a quantitative measure that provides precise density values for different tissue types, enabling objective assessment of bone quality.[21] In CT systems, HU values are calibrated based on X-ray attenuation, offering standardized and reproducible density measurements. In contrast, CBCT systems measure attenuation but express it in grayscale values rather than standardized HU units.[22]

Computed tomography is widely regarded as the reference method for quantifying bone mineral density (BMD), largely because it provides consistent HU measurements. This consistency arises from its calibrated attenuation scale, which is standardized using materials with known densities: air (-1000 HU), distilled water (0 HU), and cortical bone (approximately +1000 HU). Despite its accuracy, the substantial radiation exposure associated with CT restricts its suitability for routine diagnostic use in dentistry.[23]

Although CBCT systems display HU values, it is important to note that these do not represent true HU measurements.[24] Instead, CBCT outputs grayscale values (GVs), which multiple investigations have shown to correlate strongly with HU.[22,25] While CBCT offers advantages over CT, including lower radiation dose, shorter scan times, and high-resolution images, its inability to accurately replicate HU values remains a notable limitation.[16,24,26] Nonetheless, several studies suggest that CBCT grayscale values can still be useful for assessing bone density in clinical practice.[27-29]

A growing body of literature supports the use of CBCT-derived HU or GVs for evaluating the quality of trabecular bone.[22,28-30] Razi et al.[22] demonstrated a robust relationship between CBCT GVs and CT-based HU measurements, suggesting that CBCT may represent a low-dose and cost-effective alternative for assessing bone density, particularly during implant planning. Singh et al.[29] further endorsed this application by categorizing implant-site bone quality using HU values obtained from CBCT, noting important regional differences and underscoring its relevance to preoperative assessment. Dahiya et al.[28] similarly confirmed the utility of CBCT HU values in the posterior mandible, reporting strong predictive performance for identifying implant sites with moderate to high bone density. Collectively, these studies justify the inclusion of CBCT-derived HU values in the present study's evaluation of trabecular bone. Kim et al.[30] provided additional evidence by comparing HU measurements with detailed trabecular microarchitectural features—such as trabecular thickness, spacing, number, and bone volume fraction—across several craniofacial regions in 58 patients. They observed significant positive associations between HU and trabecular thickness, number. Their findings indicate that CBCT HU measurements can reflect underlying trabecular structure and serve as quantitative indicators of bone mineral density.

In the present study, HU values were not used as absolute indicators of bone density in isolated jaw regions. Instead, these measurements served to facilitate relative comparisons within the same individual by analyzing corresponding regions in the affected and contralateral unaffected jaws, thus providing an internal biological control. These paired regions represented two comparative groups: one affected by cysts and nutrient canals, and the other unaffected. This approach allowed us to support our qualitative visual assessments with relative numerical data, increasing the objectivity and reliability of the trabecular bone classification employed.

The integration of qualitative visual assessment with quantitative grading using the modified Lekholm and Zarb classification provides a more comprehensive evaluation of cyst-associated bone changes. This combined approach represents a methodological advance over earlier studies that predominantly relied on visual or subjective assessment alone.

Combining qualitative (visual) and quantitative (modified Lekholm and Zarb) assessments allowed a comprehensive evaluation of bone changes around cysts, differing from previous studies that often relied solely on visual analysis. Our CBCT findings confirm a significant association between nutrient canals and sclerotic bone. Moreover, applying the modified Lekholm and Zarb classification to CBCT images is a novel approach, demonstrating that this CT-based system can be adapted for CBCT to provide more standardized and quantitative bone quality assessment, improving reproducibility.

In this study, the nutrient canals in cyst-affected regions were more frequently identified in areas demonstrating an "above average" trabecular bone pattern on visual evaluation and corresponding to the Q1 category of the modified Lekholm and Zarb classification. This increased presence of nutrient canals in sclerotic bone likely reflects a reactive adaptation to greater local vascular requirements. Clinically, recognizing the higher likelihood of nutrient canals in sclerotic bone around cysts can enhance CBCT reporting and surgical planning, helping to avoid complications such as bleeding or nerve injury.

The significant association between the two classification systems suggest that the modified Lekholm and Zarb classification could be a reliable alternative to subjective visual assessment. However, unlike trabecular density, nutrient canal presence alone was not significantly linked with sclerosis in lesion-free jaws, partly due to the small sample size in this subgroup. Larger studies including more lesion-free jaws with nutrient canals are needed to clarify this relationship.

Limitations include the relatively small sample size and the absence of histopathological confirmation for all lesions, leading to reliance on preliminary radiographic diagnoses to prevent data loss. This study serves as preliminary evidence highlighting that increased trabecular sclerosis around cysts may coincide with a higher prevalence of nutrient canals. Further research with larger, histologically confirmed cyst subgroups is warranted to corroborate our findings.

Conclusions

Careful documentation of nutrient canals in CBCT reports is important, as they appear more often in sclerotic bone adjacent to jaw cysts, with implications for surgical risk management. The modified Lekholm and Zarb classification offers a promising, objective alternative to visual trabecular assessment in CBCT-based bone quality evaluation.

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Conflicts of Interest Statement

The authors declare that they have no conflict of interest.

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