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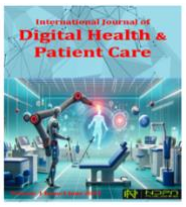

Prevalence of Nutrient Canals in Mandibular Anterior Periapical Radiographs and Their Relationship with Chronic Systemic Diseases and Periodontitis

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ABSTRACT

Aim: Nutrient canals are anatomical pathways within the jawbone containing small blood vessels and nerves that provide essential nutrients and oxygen to the bone. This study aimed to evaluate the prevalence of nutrient canals in mandibular anterior periapical radiographs and to assess their possible association with chronic systemic diseases such as diabetes, hypertension, and periodontitis. **Methods:** This retrospective study was conducted between July 2023 and August 2025 at the Faculty of Dentistry, Zonguldak Bülent Ecevit University and included 105 patients with diabetes, hypertension, or periodontitis, as well as 35 healthy controls. The presence and number of nutrient canals were assessed on periapical radiographs of the mandibular anterior region. **Results:** The study found that nutrient canals were present in over half of the participants. Their occurrence was notably more common among individuals with diabetes, hypertension, and periodontitis compared to those without any systemic condition.(p:0,003)There was no meaningful difference between women and men(p:0,89), while the middle-aged group showed the highest frequency of these canals.(p:0,025) **Conclusion:** The increased presence of nutrient canals in individuals with diabetes, hypertension, and periodontitis suggests a potential link between these systemic diseases and jawbone microvascular changes. Detection of nutrient canals on periapical radiographs may aid in identifying early signs of undiagnosed systemic conditions.

1. INTRODUCTION

Nutrient canals are defined as fine anatomical spaces within the mandibular and maxillary alveolar bone through which blood vessels and nerves pass, playing a crucial role in the nourishment of teeth and surrounding tissues [1,2]. First described by Hirschfeld in 1923, these structures are also referred to as *interdental*, *vascular*, or *circulatory canals* [1,6]. Radiographically, they are most commonly observed in the anterior region of the mandible as vertically oriented radiolucent lines between the tooth roots or below the apices [3,5].

While some researchers consider nutrient canals as normal anatomical structures, others have associated their visibility with systemic or pathological conditions such as diabetes mellitus, hypertension, periodontitis, tuberculosis, calcium deficiency, disuse atrophy, and aortic coarctation [3,4,5]. The frequency with which these canals are observed is influenced by various factors, including bone density, trabecular pattern, cortical thickness, age, gender, and edentulism [4,6].

Intraoral periapical radiographs are among the most suitable two-dimensional imaging modalities frequently used for the assessment of nutrient canals [3,5]. However, these techniques may be inadequate for the precise evaluation of canal position and diameter; therefore, the use of cone-beam computed tomography (CBCT) has become increasingly prevalent [6]. CBCT provides high accuracy in identifying critical anatomical structures in the mandibular anterior region prior to surgical procedures and helps prevent potential complications [6,10].

A growing body of recent research has explored the relationship between nutrient canals and systemic diseases. In particular, studies have focused on the potential effects of systemic conditions such as diabetes, hypertension, and periodontitis on the visibility and morphology of nutrient canals, emphasizing their clinical significance [1–9].

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The development of artificial intelligence–based models for the automatic detection and analysis of the morphological characteristics of nutrient canals represents a significant advancement in improving diagnostic accuracy and strengthening clinical applications [9]. Such technological innovations enable a more precise assessment of canal anatomy and support individualized treatment planning, particularly in implant dentistry [9].

Therefore, the presence and characteristics of nutrient canals should be regarded not only as anatomical variations but also as potential radiographic indicators of systemic conditions such as diabetes, hypertension, and periodontitis [2,3,5,6]. For this reason, evaluating the prevalence, diameter, and morphology of nutrient canals in the mandibular anterior region across different patient groups holds substantial clinical and scientific importance [1,3,9].

The aim of this study was to investigate the prevalence of nutrient canals on mandibular anterior periapical radiographs and to statistically evaluate their possible relationship with chronic systemic diseases such as diabetes, hypertension, and periodontitis.

2. MATERIALS AND METHODS

2.1. Participants

This retrospective study was conducted between July 2023 and August 2025 at the Faculty of Dentistry, Zonguldak Bülent Ecevit University. The study population consisted of 140 individuals, including 105 patients diagnosed with diabetes mellitus, hypertension, or chronic periodontitis, and 35 systemically healthy individuals who served as the control group. Participants were categorized into four distinct groups: systemically healthy individuals (control group), patients with diabetes mellitus, patients with hypertension, and patients diagnosed with chronic periodontitis. Patients with diabetes mellitus were included only if they had been under medical treatment for at least one year and showed fasting plasma glucose levels below 120 mg/dL and HbA1c values below 8%.

These thresholds were selected to ensure the inclusion of patients with relatively controlled diabetes, as previous studies have demonstrated that chronic diabetes-related microvascular alterations may persist even under metabolic control and may influence intraosseous vascular structures such as nutrient canals. At the same time, excluding patients with poorly controlled diabetes reduced the potential confounding effects of severe metabolic imbalance and advanced systemic complications on alveolar bone morphology and radiographic interpretation[1,5,7,10].

The data of patients who consented to the use of their radiographic records were included in the study. Ethical approval was obtained from the Non-Interventional Ethics Committee of Zonguldak Bülent Ecevit University (Meeting No: 2025/02).

2.2. Research Process

Mandibular anterior periapical radiographs were retrospectively evaluated to determine the presence and number of nutrient canals.All radiographs were independently evaluated by two experienced oral radiologists with comparable clinical experience (5 and 9 years, respectively) Demographic data, including age, gender, and systemic disease history, were recorded for all participants.

2.3. Data Collection Techniques

Nutrient canals were identified on periapical radiographs as thin, well-defined radiolucent lines with a vertical or slightly oblique orientation, extending through the alveolar bone. They were most commonly observed in the anterior mandible, either between adjacent tooth roots or inferior to the root apices.

Radiolucent lines that could not be clearly distinguished from normal trabecular bone patterns, lamina dura interruptions, or possible fracture lines were excluded from evaluation. The identification criteria were based on previously published radiographic descriptions of nutrient canals in intraoral periapical imaging [3,11,12].

Radiographs were obtained using the parallel technique at 70 kVp and 16.3 mGy·cm^2, with an exposure time ranging from 0.08 to 0.13 seconds. Only radiographs of sufficient diagnostic quality were included in the analysis.

The inclusion criteria were as follows: individuals aged over 18 years; patients diagnosed with and under treatment for diabetes for at least one year, with fasting plasma glucose levels below 120 mg/dL and HbA1c below 8%; patients diagnosed with and under controlled treatment for hypertension for at least one year; and patients diagnosed with periodontitis during treatment planning, showing horizontal or vertical bone loss of 2 mm or more from the cemento-enamel junction on panoramic radiographs.

The exclusion criteria were radiographs of insufficient quality (e.g., low resolution or blurring); patients with advanced forms of periodontal disease; individuals under 18 years of age; and patients with other major systemic diseases such as cancer or severe infections.

Cases with extensive edentulism or absence of mandibular anterior teeth were excluded from the study, as tooth loss has been shown to affect alveolar bone morphology and trabecular patterns, which may influence the radiographic visibility of nutrient canals.

Patients with limited tooth loss that did not compromise the diagnostic evaluation of the mandibular anterior region were included, provided that the radiographic image quality was sufficient [4,6,11,12].

2.4. Statistical Analysis

All data were analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). The chi-square test and independent samples t-test were used for group comparisons. A p-value of less than 0.05 was considered statistically significant when evaluating the relationships between the presence of nutrient canals and systemic diseases, age, and gender.

3. RESULTS

In this retrospective study, a total of 140 mandibular anterior periapical radiographs were examined. Among the participants, 84 (60%) were female and 56 (40%) were male, with a mean age of 44.4 ± 13.6 years. The study group consisted of 75% individuals with systemic diseases and 25% healthy controls (Table 1). Nutrient canals were observed in 52.9% of all cases, whereas 47.1% showed no canal presence (Table 1). When evaluated by group, the prevalence of nutrient canals was similar in the diabetes (62.9%), hypertension (62.9%), and periodontitis (60.0%) groups, all of which demonstrated significantly higher rates compared with the control group ($p < 0.05$) (Table 1). In the control group, nutrient canals were detected in only 25.7% of participants, while 74.3% showed no visible canals. The difference between the systemic disease groups and the control group was statistically significant ($p < 0.05$) (Table 1).

Table 1. Relationship between systemic diseases and the frequency of nutrient canals

Groups	Absent (n)	Present(n)	Total (n)	% Absent	% Present	P - value
Diabetes Mellitus	13	22	35	37.1	62.9	
Hypertension	13	22	35	37.1	62.9	
Chronic Periodontitis	14	21	35	40.0	60.0	0.003
Controls	26	9	35	74.3	25.7	
Total	66	74	140	47.1	52.9	

Among female participants, 52.4% exhibited nutrient canals, whereas 53.6% of males showed their presence. No statistically significant difference was found between genders ($p > 0.05$) (Table 2).

Table 2. Relationship between gender and the presence of nutrient canals

Gender	Absent (n)	Present (n)	Total (n)	% Absent	% Present	P - value
Famale	40	44	84	47.6	52.4	
Male	26	30	56	46.4	53.6	0.89
Total	66	74	140	47.1	52.9	

When participants were categorized into five age groups, the prevalence of nutrient canals was 26.7% in the 20–29 age group, 55.6% in 30–39, 57.9% in 40–49, 65.6% in 50–59, and 59.1% in 60–70 years. Although nutrient canals were observed more frequently among individuals aged 50–59 years, this difference was not statistically significant ($p > 0.05$)(Table 3).

Table 3. Relationship between age groups and the prensece of nutrient canals

Age Group	Absent (n)	Present(n)	Total (n)	% Absent	% Present	P - value
20-29	22	8	30	73.3	26.7	
30-39	8	10	18	44.4	55.6	
40-49	16	22	38	42.1	57.9	0.003
50-59	11	21	32	34.4	65.6	
60-69	9	13	22	40.9	59.1	
Total	66	74	140	47.1	52.9	

4. DISCUSSION

Nutrient canals are radiolucent structures most frequently identified in the anterior mandible on intraoral radiographs and have historically been described as incidental anatomical variations. Early radiographic descriptions emphasized their anatomical nature; however, subsequent investigations began to question this assumption by reporting higher prevalence rates in patients with systemic diseases, thereby suggesting a possible diagnostic or pathophysiological relevance [11,12].

Prabhu et al. were among the early investigators to demonstrate that nutrient canals were significantly more prevalent in hypertensive patients compared with normotensive controls, proposing that chronic elevation of blood pressure could lead to vascular remodeling and increased visibility of intraosseous vascular channels [11,12]. This observation shifted the interpretation of nutrient canals from a purely anatomical finding toward a potential indicator of systemic vascular alterations.

Subsequently, Vanaja et al. expanded this concept by evaluating multiple systemic and periodontal conditions simultaneously and reported markedly higher nutrient canal prevalence in patients with diabetes mellitus, hypertension, and periodontitis when compared with healthy individuals [12]. Their findings suggested that nutrient canal visibility may reflect a common pathway involving microvascular changes and chronic inflammatory burden rather than disease-specific effects alone. Although periodontitis is primarily a localized inflammatory disease, its well-documented systemic inflammatory and microvascular effects may lead to radiographic changes comparable to those observed in systemic conditions.

Chandini et al. further supported this hypothesis by demonstrating a progressive increase in nutrient canal prevalence in diabetic patients and those with combined systemic conditions, emphasizing the role of chronic hyperglycemia and associated microangiopathy in altering intraosseous vascular patterns [13]. The significantly higher prevalence observed in the diabetic group in the present study is in close agreement with these findings and reinforces the proposed microvascular mechanism.

Using digital intraoral radiography, Amoun and Badur reported increased nutrient canal detection in hypertensive patients while finding no statistically significant association with gender [14]. Their results highlighted both the influence of systemic disease and the limited role of demographic variables in determining nutrient canal visibility. The absence of a gender-related association in the present study is consistent with their conclusions.

Periodontal disease has also been repeatedly implicated in the increased detection of nutrient canals. Muley et al. reported significantly higher prevalence of nutrient canals in patients with periodontitis and suggested that chronic periodontal inflammation may stimulate localized vascular proliferation within the alveolar bone [15]. Similarly, other periodontal-focused studies have emphasized that sustained inflammatory processes may alter bone microarchitecture, thereby enhancing the radiographic conspicuity of nutrient canals.

Salaie et al., in a population-based radiographic study, examined the influence of age and gender on nutrient canal presence and reported that although nutrient canals were more frequently observed in older age groups, these differences did not reach statistical significance when age was considered independently [16]. This finding supports the interpretation that age may act as a modifying factor rather than a primary determinant, which is consistent with the lack of statistically significant age-related differences observed in the present study.

Bhandarkar et al. discussed nutrient canals as potential radiographic indicators of systemic disease, emphasizing that their increased prevalence in medically compromised patients should prompt clinicians to consider underlying systemic conditions during radiographic evaluation [17]. This interpretive approach aligns with the clinical implications of the present findings.

Torkian et al. further highlighted the association between hypertension and nutrient canal visibility, proposing that routine dental radiographs could serve as an adjunctive screening tool for systemic vascular conditions when interpreted carefully [18]. The higher prevalence observed in the hypertensive group in the current study supports this perspective.

Sudha et al. examined nutrient canal prevalence across mixed systemic and periodontal conditions and reported consistently higher rates in diseased groups compared with healthy controls, reinforcing the notion that nutrient canals are more closely associated with pathological states than with normal anatomical variation [19].

Singh et al. evaluated demographic influences and reported no consistent association between gender and nutrient canal presence, while age-related trends were described as inconsistent and dependent on disease status rather than chronological aging alone [20]. These observations parallel the findings of the present study, in which

neither age nor gender showed a statistically significant association with nutrient canal prevalence.

Saravan et al. emphasized the clinical relevance of nutrient canals in dental radiology, suggesting that their identification should not be overlooked, particularly in patients with known or suspected systemic disease [21]. This recommendation supports the broader clinical interpretation of the present results.

Dhir et al. specifically focused on periodontal pathology and reported increased nutrient canal detection in patients with chronic periodontitis, attributing this finding to prolonged inflammatory vascular responses within the alveolar bone [22]. The higher prevalence observed in the periodontitis group in the present study is consistent with their conclusions.

Ashima Bali et al. investigated diabetic populations and reported significantly higher nutrient canal prevalence compared with non-diabetic controls, further supporting the role of diabetes-related microvascular alterations in enhancing nutrient canal visibility [23].

Hasan et al. evaluated demographic parameters and concluded that gender does not exert a significant influence on nutrient canal detection, reinforcing the growing consensus that demographic factors play a limited role compared with systemic disease status [24].

Tümer et al. underscored the importance of recognizing nutrient canals during routine radiographic assessment and suggested that such findings may complement clinical evaluation by raising suspicion for underlying systemic conditions [25].

Taken together, the present findings demonstrate strong concordance with previously published data and provide further evidence that nutrient canals are more closely associated with systemic and inflammatory diseases particularly diabetes mellitus, hypertension, and periodontitis than with demographic factors such as age or gender. The cumulative literature supports the interpretation of nutrient canals as potential radiographic markers of altered vascular and inflammatory states rather than incidental anatomical variations.

From a clinical standpoint, careful evaluation of nutrient canals on routine dental radiographs may offer valuable adjunctive information regarding a patient's systemic health status. Given the often asymptomatic nature of conditions such as diabetes mellitus and hypertension, dental radiographic findings may contribute to early recognition and timely referral for further medical assessment.

This study has several limitations. First, since the participants were recruited from a single center, regional demographic characteristics may have influenced the findings, limiting the generalizability of the results to other populations. In addition, as the evaluations were based on two-dimensional periapical radiographs, the inherent limitations of image superposition and resolution could have led to misinterpretations.

5. Conclusion

This study demonstrated that the prevalence of nutrient canals in the mandibular anterior region is associated with chronic systemic diseases such as diabetes mellitus, hypertension, and periodontitis. A significantly higher presence of nutrient canals was observed in individuals with systemic conditions, suggesting that these structures may be sensitive to microcirculatory alterations within the alveolar bone. Although age did not show a statistically significant association with nutrient canal prevalence, an age-related increasing trend was observed, which may reflect physiological changes in bone metabolism and vascular architecture that become more apparent radiographically over time.

These findings indicate that nutrient canals should not be regarded solely as anatomical variations, but rather as potential radiographic indicators of systemic vascular and inflammatory changes. Careful evaluation of nutrient canals during routine dental radiographic examinations may contribute to the early identification of chronic systemic diseases, particularly diabetes mellitus and hypertension. In addition, assessment of nutrient canals in patients with periodontitis may provide supplementary information regarding alveolar bone status and support clinical decision-making and treatment planning.

Future studies with larger and more diverse populations, including different age groups, genders, and systemic conditions, are warranted to further elucidate these associations. The use of high-resolution imaging modalities, such as cone-beam computed tomography, may enhance the visualization and characterization of nutrient canals. Furthermore, the integration of artificial intelligence–based image analysis systems for automated detection, along with interdisciplinary approaches combining clinical, radiological, and biochemical data, may further clarify the diagnostic potential of nutrient canals as radiographic indicators of systemic health.

Conflict of Interest

No conflict of interest is declared by tehe authors. In addition, no financial support was received.

Ethics Committee

The study protocol was approved by the Ethics Committee of Non-Interventional Ethics Committee of Zonguldak Bülent Ecevit University (Meeting No: 2025/02).

Author Contributions

Study Design, UCH; Data Collection, UCH,ÇŞ; Statistical Analysis, UCH, ÇŞ; Data Interpretation, UCH; Manuscript Preparation, UCH, ÇŞ, GG; Literature Search, UCH, ÇŞ, GG. All authors have read and agreed to the published version of the manuscript.

REFERENCES

1. Abdar-Esfahani, M., & Mehdizade, M. (**2014**). Mandibular anterior nutrient canals in periapical radiography in relation to hypertension. *Nephro-Urology Monthly, 6*(1), e15292. [CrossRef] [PubMed]
2. Balla, S., Bavara, S., Alapati, S., Damarasingu, R., Yerramalla, P., & Ambavaram, N. (**2020**). Prevalence of nutrient canals in digital radiographs with correlation to systemic conditions. *International Journal of Innovative Science and Research Technology, 5*(8), 1751–1754. [CrossRef]
3. Castelino, R. L., Babu, S., Shetty, S. R., Laxmana, A. R., & Balan, P. (**2015**). Can intraoral periapical radiographs be used as an adjunct diagnostic marker in detecting underlying systemic diseases? *ÇukurovaMedical Journal, 40*(4), 661–669. [CrossRef]
4. Gupta, P., Naik, S. R., Tiwari, A., & Gupta, M. (**2017**). Nutrient canals of the alveolar process as an anatomical feature for age and gender determination. *Journal of Indian Academy of Oral Medicine and Radiology, 29*(4), 358–361. [CrossRef]
5. Kaul, V., Kaul, R., Ahmed, R., Singh, S., & Kapoor, M. (**2017**). Incidence of mandibular nutrient canals in a hypertensive and diabetic population: A prospective cross-sectional radiographic study. *IP International Journal of Maxillofacial Imaging, 3*(4), 120–123. [CrossRef]
6. Rathod, S. R., Lathiya, V., Rathod, Y., & Bhide, A. (**2022**). Assessment of mandibular anterior nutrient canals in patients with and without periodontal disease: A cone-beam computed tomographic study. *Journal of Indian Academy of Oral Medicine and Radiology, 34*(3), 329–332. [CrossRef]
7. Kaur, S., Verma, P., & Saigal, A. (**2019**). Evaluation of mandibular anterior nutrient canals in hypertensive and diabetes mellitus patients: A comparative radiographic study. *Tzu Chi Medical Journal, 31*(2), 118–123. [CrossRef] [PubMed]
8. Manja, C. D., Boel, T., & Reska, A. G. (**2021**). Prevalence of nutrient canals in hypertensive and non-hypertensive patients using periapical radiographs. *Natural Volatiles & Essential Oils, 8*(4), 4055–4062.
9. Pawar, A. R., Yadalam, P. K., Kaarthikeyan, G., & Ardila, C. M. (**2022**). Explainable self-supervised learning to predict and generate nutrient canal diameters from mandibular cone-beam computed tomography analysis. *BioMed Research International, 2022*, 5542030. [CrossRef]
10. Qaseem, A., Wilt, T. J., Kansagara, D., Horwitch, C., Barry, M. J., Forciea, M. A., & Clinical Guidelines Committee of the American College of Physicians. (**2018**). Hemoglobin A1c targets for glycemic control with pharmacologic therapy for nonpregnant adults with type 2 diabetes mellitus: A guidance statement update from the American College of Physicians. *Annals of Internal Medicine, 168*(8), 569–576. [PubMed]
11. Prabhu, N., Keluskar, V., Ammanagi, R., & Issrani, R. (2**013**). An intraoral periapical radiographic study of mandibular nutrient canals with conventional and digital radiography in hypertensive patients: A comparative study. *International Journal of Perioperative Ultrasound and Applied Technologies, 2*(1), 19–25. [CrossRef]
12. Vanaja, R., Reddy, V. G., Ali, I. M., & Shashikanth, M. C. (**2008**). An intraoral periapical radiographic study of nutrient canals as a diagnostic aid in systemic diseases and pathological conditions. *Journal of Indian Academy of Oral Medicine and Radiology, 20*(2), 49–55. [CrossRef]
13. Chandini, K. V., Mishra, S., Bharani Krishna, T., Prabhat, M. P. V., & Sarat, G. (**2020**). Nutrient canals Tell-tale signs of transmogrifying systemic diseases. *Saudi Journal of Medical and Pharmaceutical Sciences, 6*(8), 559–566. [CrossRef]
14. Amoun, A., & Badur, S. (**2022**). Evaluation of nutrient canals by intraoral digital radiography technique for hypertensive patients. *Tishreen University Journal for Research and Scientific Studies Health Sciences Series, 44*(5), 561–569.
15. Muley, A., Bhandarkar, G., & Saravan, R. (**2014**). Radiographic evaluation of nutrient canals in periodontal disease. *Journal of Oral Medicine and Radiology, 26*(3), 345–350.
16. Salaie, R. N., Meran, Z. D., Star, B., Nahro, D., & Badrkhan, H. (**2023**). Correlation between age and gender with the presence of anterior mandibular nutrient canals in a sample of patients. *Eurasian Journal of Science and Engineering, 9*(3), 57–66. [CrossRef]
17. Bhandarkar, G., Muley, A., & Saravan, R. (**2015**). Nutrient canals as radiographic indicators of systemic diseases. *Journal of Clinical and Diagnostic Research, 9*(8), ZC01–ZC04.
18. Torkian, P., Gholami, M., & Shokri, A. (**2019**). Radiographic appearance of nutrient canals in hypertensive patients: A comparative study. *Iranian Journal of Radiology, 16*(2), e84512.
19. Sudha, M., Nageswara Rao, S., & Prabhat, M. P. V. (**2016**). Prevalence of nutrient canals in patients with systemic and periodontal diseases. *Journal of Oral and Maxillofacial Radiology, 4*(1), 12–17.

20. Singh, A., Singh, S., & Verma, P. (**2017**). Age- and gender-related variations in mandibular nutrient canals: A radiographic study. *International Journal of Oral Health Sciences, 7*(2), 67–71.
21. Saravan, R., Muley, A., & Bhandarkar, G. (**2015**). Clinical relevance of nutrient canals in dental radiology. *Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology, 1*(3), 120–124.
22. Dhir, S., Verma, R., & Kaur, J. (**2018**). Nutrient canals as indicators of periodontal pathology: A radiographic study. *Journal of Indian Society of Periodontology, 22*(5), 420–424.
23. Bali, A., Kaur, M., & Singh, P. (**2019**). Radiographic evaluation of nutrient canals in diabetic patients. *Journal of Oral Biology and Craniofacial Research, 9*(2), 134–138.
24. Hasan, S., Tümer, A., & Yılmaz, H. (**2020**). Demographic factors affecting the radiographic visibility of nutrient canals. *European Journal of Dentistry, 14*(4), 601–606.
25. Tümer, A., Hasan, S., & Demir, A. (**2021**). Diagnostic significance of nutrient canals in routine dental radiographs. *Imaging Science in Dentistry, 51*(3), 245–252.