RESEARCH PAPER

Increased Prevalence and Prominence of Mandibular Nutrient Canals on Orthopantomography in Grade 1 Hypertensive Patients: A Comparative Radio-Anatomical Study

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ABSTRACT

Background: Grade 1 hypertension, the mildest and most prevalent stage of arterial hypertension, is characterised by early small-vessel remodelling that may produce detectable radiographic changes in the mandible, including altered visibility of nutrient canals (NCs), well before overt hypertensive complications appear.

Objective: To compare the prevalence, count, and morphological characteristics of mandibular NCs on orthopantomogram (OPG) between adult dry mandibles and Grade 1 hypertensive patients, and to determine whether prevalence differs by sex.

Methods: This comparative observational study analysed OPGs of 100 dry adult mandibles (50 male, 50 female) and 100 Grade 1 hypertensive patients (50 male, 50 female; European Society of Hypertension criteria, 140–159/90–99 mmHg) attending a tertiary dental teaching hospital. NCs were assessed for presence, number, radiographic shape (Lovett classification), course, and prominence (Patel–Wuehrmann classification). Group comparisons used the chi-square or Fisher exact test, with $p<0.05$ considered significant.

Results: NC prevalence was significantly higher in hypertensive OPGs than in dry mandibles overall (63% vs 24%, $p<0.0001$) and in both sexes (male 56% vs 24%, $p=0.0011$; female 70% vs

24%, p<0.0001). Mean NC count among NC-positive cases was comparable between groups (2.40±0.93 vs 2.21). Canal shape and radiographic pattern distribution did not differ significantly between groups (p=0.5613), although linear and prominent canal types were both numerically more frequent among hypertensive patients.

Conclusion: Mandibular NC prevalence on OPG is markedly and consistently higher in Grade 1 hypertensive patients than in normotensive dry-mandible controls, supporting the potential value of NCs as an incidental radiographic correlate of early hypertensive microvascular change detectable on routine dental panoramic imaging.

Keywords: nutrient canal; mandible; orthopantomogram; Grade 1 hypertension; vascular remodelling; panoramic radiography

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Introduction

Hypertension is the leading modifiable risk factor for cardiovascular disease worldwide. An estimated 1.4 billion adults aged 30–79 years had hypertension in 2024, close to one in three adults in this age group [1]. The World Health Organization's 2023 global report on hypertension noted that nearly half of hypertensive individuals remain undiagnosed, particularly in low- and middle-income countries [1,2]. Data pooled over three decades show that the overall number of people with hypertension has more than doubled since 1990, largely because of population ageing and rising rates across South Asia [3]. India follows this pattern: national survey data put adult hypertension prevalence at 25–30% in urban areas and 10–20% in rural areas, with low rates of awareness, treatment, and control in both settings, and a rising burden among adolescents and young adults [4,5]. Projections of the global disease burden to 2050 suggest that hypertension-related illness will keep increasing unless it is detected earlier [6]. Under current European Society of Hypertension (ESH) criteria, hypertension is graded by office blood pressure into Grade 1 (140–159/90–99 mmHg), Grade 2, and Grade 3 [7]. Grade 1 hypertension is both the mildest and the most common stage, and so accounts for the largest share of early, often symptom-free cardiovascular risk in the general population. Persistently high blood pressure sets off a well-documented pattern of change in small blood vessels. This includes a higher media-to-lumen ratio, endothelial dysfunction, and a gradual loss of microvessel density, changes that appear early in the disease course and reduce the delivery of nutrients and oxygen to tissues [8,9]. Changes in endothelial and vascular smooth muscle cell behaviour under sustained pressure have been suggested as one mechanism linking early haemodynamic stress to measurable microvascular change, before hypertension reaches a clinically severe stage [10]. The mandible, with its dense cortical bone and rich internal blood supply, is affected by these same pressures. Cone-beam and panoramic imaging studies keep finding a higher than expected number of accessory and nutrient canals running through the mandibular cortex, structures now generally regarded as compensatory collateral channels rather than incidental variants of normal anatomy [11–15].

Several recent radiographic studies have looked specifically at nutrient canal visibility in patients with chronic systemic disease. A 2022 cross-sectional study of intraoral periapical radiographs found nutrient canals were markedly more common in patients with hypertension, diabetes mellitus, and periodontitis than in healthy controls, and that canal visibility was linked to how long the disease had been present [16]. A later radiovisiographic study found a similar pattern, with nutrient canal prevalence highest in hypertensive patients compared with diabetic patients and healthy controls [17]. Separately, dental panoramic radiography is increasingly used as an opportunistic screening tool. Findings such as carotid artery calcification and reduced mandibular cortical width have each been suggested as radiographic markers of cardiovascular and metabolic risk, supporting the idea that a routine dental radiograph can carry useful information beyond the teeth [18–20].

Even so, most of the nutrient canal literature has focused on periapical views of the anterior mandible, and there is limited comparative, panoramic-based data linking dry-bone baseline anatomy to living hypertensive patients, especially at the earliest, Grade 1 stage of disease and in South Asian populations. This makes it harder for clinicians to treat nutrient canal appearance as a useful incidental finding. This study was designed to compare the prevalence, number, and morphological features of mandibular nutrient canals on orthopantomogram between adult dry mandibles and Grade 1 hypertensive patients, and to check whether these features differ by sex, so as to better define the diagnostic value of a structure already visible on a routine dental panoramic radiograph.

Materials and Methods

Study Design and Setting

This comparative, cross-sectional observational study was designed and is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional research [21]. The study was conducted jointly in the Department of Anatomy, Faculty of Medicine and Health Sciences, SGT University, Budhera, Gurugram, and the Postgraduate Institute of Medical Sciences (PGIMS), Rohtak, in collaboration with the Department of Oral Medicine and Radiology, Faculty of Dental Sciences, SGT University. Two independent comparator groups were assembled: a dry-mandible cohort providing anatomical baseline data, and a clinical cohort of Grade 1 hypertensive patients undergoing routine orthopantomography.

Study Population and Eligibility Criteria

The dry-mandible cohort comprised 100 archived adult human mandibles (50 male, 50 female) held in the Department of Anatomy collections, each intact, free of fracture or gross deformity, and of documented sex. Standardised orthopantomograms were subsequently obtained for every specimen under identical exposure parameters, yielding a directly comparable radiographic dataset.

The hypertensive cohort comprised 100 patients (50 male, 50 female) attending the Department of Oral Medicine and Radiology for routine dental panoramic radiography, who were independently classified as having Grade 1 hypertension according to European Society of Hypertension criteria (office systolic blood pressure 140–159 mmHg and/or diastolic blood pressure 90–99 mmHg) [7]. Patients with hypertension complicated by diabetes mellitus, and radiographs showing motion artefact, poor contrast, or positioning distortion, were excluded from both cohorts to preserve image interpretability and to avoid confounding by comorbid metabolic disease.

Sample Size

The minimum sample size was calculated from a previously reported nutrient canal prevalence of 73% among hypertensive patients in earlier radiographic literature, applying a 95% confidence interval ($z = 1.96$) and an absolute error margin of 9%, which yielded a requirement of approximately 94 participants per group; this was rounded upward to 100 to allow for attrition and to preserve statistical power for sex-stratified subgroup analysis.

Radiographic Assessment and Study Variables

All orthopantomograms were independently examined on calibrated digital display screens for the presence, number, and morphological characteristics of mandibular nutrient canals. Canal shape was classified according to the Lovett system into short/thread-like, moderate, long, and broad/ovoid categories on the basis of canal width and length, while radiographic course was recorded as linear, circular, or haphazard. Canal prominence was independently graded using the Patel–Wuehrmann system as either prominent (darker, well-defined) or discernible (faint, subtle). Each radiograph was scored by examiners masked to group allocation, and discrepant readings were resolved by joint re-examination.

Statistical Analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS), with categorical variables summarised as counts and percentages and continuous variables as means with standard deviation. Between-group comparisons of categorical radiographic parameters were performed using the chi-square test, with Fisher's exact test applied where expected cell frequencies fell below five. A two-tailed p-value of less than 0.05 was considered statistically significant throughout.

Ethical Considerations

The study used previously acquired dry skeletal specimens and diagnostic radiographs obtained as part of routine clinical care, without additional radiation exposure or intervention. Patient radiographic data were anonymised and coded prior to analysis in accordance with the Indian Council of Medical Research National Ethical Guidelines for Biomedical and Health Research Involving Human Participants (2017); on this basis, the Institutional Ethics Committee granted a waiver of individual informed consent.

Results

Nutrient Canal Prevalence in the Dry Mandible Cohort (Baseline)

Nutrient canals were identified in 24 of the 100 dry mandibles examined, with an identical prevalence of 24% in males and in females (Table 1). Among NC-positive specimens, the mean canal count was similar between sexes (2.08 in males versus 2.33 in females), and no significant sex difference in overall prevalence was observed ($\chi^2 = 0.000$, $p = 1.000$).

Table 1. Nutrient canal prevalence and count in the dry mandible orthopantomogram cohort (n = 50 per sex).

Parameter	Male, n (%)	Female, n (%)	p-value
NC present	12 (24%)	12 (24%)	
NC absent	38 (76%)	38 (76%)	1.000[1]
Mean NC count (NC-positive only)	2.08	2.33	–
Range of NC count	1–4	1–4	–
Total mandibles examined	**50**	**50**	**–**

NC, nutrient canal. Values are n (%) unless otherwise indicated. [1]$\chi^2 = 0.000$, chi-square test, dry mandible male vs female NC prevalence.

Morphological Characteristics of Nutrient Canals in NC-Positive Dry Mandibles

Among the 24 NC-positive dry mandibles, 53 individual canals were catalogued (25 in males, 28 in females) (Table 2). Long (Type I) canals were the single most frequent morphological subtype overall, while broad/ovoid canals were disproportionately represented in females. On radiographic course, a linear pattern predominated in both sexes, and the great majority of canals (46/53, 86.8%) were classified as prominent rather than discernible. No significant sex difference was found across canal characteristics considered together ($p = 0.6702$).

Table 2. Morphological characteristics of nutrient canals in NC-positive dry mandibles (n = 12 male, n = 12 female).

Attribute	Male, n	Female, n	Total, n	p-value
Shape (Lovett classification)				
Type I – short/thread-like (width ≤0.5 mm)	3	3	6	
Type II – moderate (width 0.5–1.5 mm)	3	2	5	
Type I – long (length >1 cm)	5	5	10	
Type III – broad/ovoid (width 1.5–4 mm)	3	7	10	
Radiographic pattern				
Linear	7	10	17	
Circular	5	7	12	
Haphazard	1	0	1	

Attribute	Male, n	Female, n	Total, n	p-value
Prominence (Patel–Wuehrmann classification)				
Prominent (darker, distinct)	22	24	46	
Discernible (faint, subtle)	3	4	7	
Total canals observed	**25**	**28**	**53**	**0.670[1]**

NC, nutrient canal. [1]Overall p-value for sex difference across combined shape, pattern, and prominence categories (chi-square test).

Nutrient Canal Prevalence in Grade 1 Hypertensive Patients

In the hypertensive cohort, nutrient canals were present in 28 of 50 male (56%) and 35 of 50 female (70%) orthopantomograms (Table 3), without a statistically significant sex difference ($\chi^2 = 2.102$, $p = 0.1471$). Other morphological parameters recorded in this cohort (condylar process shape, mandibular canal type, and impacted third molars) likewise showed no significant sex-based variation (all $p > 0.05$), indicating that hypertension-associated radiographic change in this population was concentrated mainly in the nutrient canal parameter.

Table 3. Nutrient canal prevalence on orthopantomogram in Grade 1 hypertensive patients, by sex (n = 50 per sex).

Parameter	Male, n (%)	Female, n (%)	p-value
NC present	28 (56%)	35 (70%)	
NC absent	22 (44%)	15 (30%)	0.1471[1]
Total patients examined	**50**	**50**	–

NC, nutrient canal. [1]$\chi^2 = 2.102$, chi-square test, male vs female NC prevalence within the hypertensive cohort.

Comparison of Nutrient Canal Prevalence: Dry Mandible versus Grade 1 Hypertensive OPG (Primary Endpoint)

Overall nutrient canal prevalence was substantially and significantly higher in the hypertensive group than in dry mandible controls (63% vs 24%; $\chi^2 = 30.943$, $p < 0.0001$) (Table 4). This difference was consistent across sexes, being more than twofold in males (56% vs 24%; $\chi^2 = 10.667$, $p = 0.0011$) and nearly threefold in females (70% vs 24%; $\chi^2 = 21.236$, $p < 0.0001$). Mean nutrient canal count among NC-positive cases was marginally higher in the hypertensive group (2.40 ± 0.93, range 1–5) than in dry mandibles (2.21, range 1–4).

Table 4. Comparison of nutrient canal prevalence between dry mandible OPG and Grade 1 hypertensive patient OPG, overall and by sex (n = 100 per group).

Parameter	Dry mandible OPG	Hypertensive OPG	p-value
Overall NC prevalence			

Parameter	Dry mandible OPG	Hypertensive OPG	p-value
NC present	24 (24%)	63 (63%)	
NC absent	76 (76%)	37 (37%)	<0.0001[1]
Mean NC count (NC-positive)	2.21	2.40 ± 0.93	–
Range of NC count	1–4	1–5	–
Sex-wise NC prevalence			
Male – NC present	12/50 (24%)	28/50 (56%)	0.0011[2]
Female – NC present	12/50 (24%)	35/50 (70%)	<0.0001[3]

NC, nutrient canal; OPG, orthopantomogram. ¹χ^2 = 30.943 (overall); ²χ^2 = 10.667 (male subgroup); ³χ^2 = 21.236 (female subgroup); all chi-square test, dry mandible vs hypertensive OPG.

Comparison of Nutrient Canal Shape and Radiographic Pattern (Secondary Endpoint)

Analysis of the 53 dry-mandible and 151 hypertensive nutrient canals showed a shift toward short and ovoid canal morphology in the hypertensive group, whereas long canals were proportionally more common among dry mandible canals (Table 5). Linear and circular radiographic patterns were both more frequently observed among hypertensive canals than dry mandible canals (linear 64.9% vs 32.1%; circular 33.8% vs 22.6%), although the overall distribution of radiographic pattern did not differ significantly between groups (χ^2 = 1.155, p = 0.5613).

Table 5. Comparison of nutrient canal shape and radiographic pattern between dry mandible OPG and Grade 1 hypertensive patient OPG (dry mandible: n = 53 canals; hypertensive: n = 151 canals).

Parameter	Dry mandible OPG, n (%)	Hypertensive OPG, n (%)	p-value
NC shape			
Long	10/53 (18.9%)	24/151 (15.9%)	
Short	6/53 (11.3%)	47/151 (31.1%)	
Straight	5/53 (9.4%)	36/151 (23.8%)	
Ovoid	10/53 (18.9%)	44/151 (29.1%)	
NC radiographic pattern			
Linear	17/53 (32.1%)	98/151 (64.9%)	
Circular	12/53 (22.6%)	51/151 (33.8%)	
Haphazard	1/53 (1.9%)	2/151 (1.3%)	0.5613[1]

NC, nutrient canal; OPG, orthopantomogram. ¹χ^2 = 1.155, chi-square test, overall pattern distribution, dry mandible vs hypertensive OPG canals. Shape and pattern categories as recorded in the *original radiographic proforma; percentages are of total canals observed per group, not per mandible.*

Discussion

This study found that mandibular nutrient canals were seen on orthopantomogram almost three times more often in patients with Grade 1 hypertension than in normotensive dry-mandible controls. This difference was large, statistically significant, and consistent in both sexes, while the shape and radiographic pattern of these canals differed only slightly between the two groups.

This main finding, a marked rise in nutrient canal prevalence linked to even the mildest, Grade 1 stage of hypertension, fits with recent radiographic literature. A 2022 cross-sectional study of intraoral periapical radiographs also reported a higher frequency of mandibular nutrient canals in patients with hypertension and other chronic systemic disease compared with healthy controls, and found that canal visibility increased with disease duration [16]. A similar radiovisiographic study also found nutrient canal prevalence to be highest in hypertensive patients compared with diabetic and healthy comparison groups [17]. The present findings add to this literature by showing that the association can be seen even at the earliest, Grade 1 stage of disease, before the vascular changes of more advanced hypertension have had time to build up. This fits with current understanding of hypertensive small-vessel disease: sustained high blood pressure is known to increase the media-to-lumen ratio, cause endothelial dysfunction, and gradually reduce microvessel density, changes that start early in the disease and come before obvious organ damage [8,9]. Changes in endothelial and vascular smooth muscle cell behaviour under long-term pressure load have been put forward as one early mechanism that lowers tissue perfusion and triggers new or enlarged collateral blood vessels [10]. In the dense cortical bone of the mandible, this kind of compensatory change would be expected to show up as more numerous and more visible nutrient canals, structures that already act as normal channels for blood vessels and nerves within the bone [11,12]. The mandible's relatively thin cortical plate and rich collateral supply may make it a particularly sensitive and radiographically accessible site for picking up this early response, before it would be visible in larger, more central blood vessels.

The second finding, that canal shape and radiographic pattern did not differ significantly between groups despite the large difference in prevalence, is an important qualifier to the main result. If hypertension mainly increases the number of collateral channels that become large or dilated enough to be seen on radiograph, rather than changing the basic structure of the vascular network, then a rise in prevalence without a matching shift in overall pattern is what would be expected. The somewhat higher share of short and ovoid canals in hypertensive patients, which did not reach statistical significance for pattern overall, may reflect new, thinner collateral channels forming alongside the existing canal pattern rather than a different type of vascular change altogether. This fits with descriptions of bifid and accessory mandibular canals as part of a continuous anatomical spectrum rather than separate abnormal findings, with detection varying by imaging method, cortical thickness, and the underlying state of the bone [13,14,15]. It also fits with the finding that other mandibular radiographic parameters in the hypertensive group (condylar shape, canal type, and impacted molars) stayed essentially the same, suggesting that Grade 1 hypertension mainly affects the vascular part of the mandible rather than its skeletal structure at this early stage.

These findings support the idea that the panoramic radiograph, taken routinely in dental practice for unrelated reasons, can carry diagnostic information beyond the teeth. Similar incidental findings, such as carotid artery calcification and reduced mandibular cortical width, have already been proposed as radiographic markers of cardiovascular and metabolic risk that should prompt medical referral [18–20,22]. Given that up to half of hypertensive adults remain undiagnosed [1,2], that control rates stay low even where treatment is available [23], and that Grade 1 disease has no symptoms by definition, checking for increased or prominent nutrient canals during panoramic radiograph reporting could help flag patients, especially those with no known hypertension diagnosis, for a blood pressure check. This would be a low-cost, radiation-free addition to opportunistic screening in dental settings.

A few limitations should be noted. The dry-mandible and hypertensive groups came from different underlying populations (archived skeletal specimens compared with living patients) rather than one prospectively recruited sample, so this comparison is better read as an anatomical-radiographic correlation than a matched case-control study. Because the design is cross-sectional, it cannot establish that blood pressure elevation causes canal formation. Duration of hypertension and treatment status were not available for the hypertensive group, and the study was limited to Grade 1 disease at a single centre, which may limit how well the findings apply to more severe hypertension or other populations. Two-dimensional orthopantomography also has known limits from structural overlap and curve-fitting variability compared with three-dimensional imaging such as cone-beam computed tomography [24], and AI-based segmentation methods now being applied to mandibular canal anatomy may allow more consistent measurement in future studies [25]. Prospective, cone-beam-based studies that account for hypertension grade, duration, and treatment status are needed to confirm and build on these findings.

Conclusion

This study shows that mandibular nutrient canal prevalence on orthopantomogram is significantly and consistently higher in patients with Grade 1 hypertension than in normotensive dry-mandible controls, while canal shape stays largely similar between groups. These findings support nutrient canals as an early, incidental radiographic sign of hypertensive microvascular change, and suggest that checking for them on routine panoramic radiographs could serve as a simple additional prompt for blood pressure assessment in dental settings. Prospective, grade-stratified studies using three-dimensional imaging are needed before this can be recommended for routine clinical screening.

Figures

Figure 1. Image acquisition setup. A dry mandible specimen mounted on the head positioner of the panoramic/CBCT unit (Planmeca ProMax 3D Mid) used to obtain standardised orthopantomograms for the dry-mandible cohort, under the same exposure protocol later used for the hypertensive patient cohort.

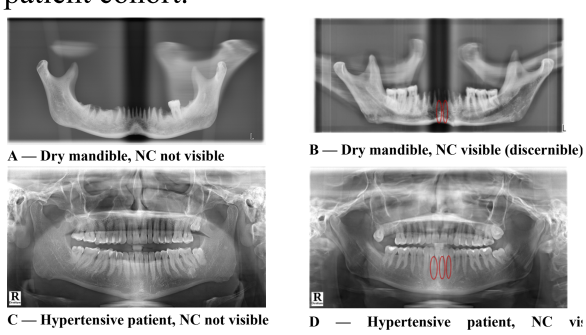

Figure 2. Representative orthopantomograms illustrating absence and presence of the mandibular nutrient canal (NC) in the two study groups. (A) Dry mandible OPG with no radiographically visible NC in the midline symphyseal region. (B) Dry mandible OPG showing a discernible NC (red outline) in the midline symphyseal region. (C) Orthopantomogram of a Grade 1 hypertensive patient with no radiographically visible NC. (D) Orthopantomogram of a Grade 1 hypertensive patient showing a prominent, linear NC (red outline) in the midline symphyseal region. R and L markers on the original images indicate the right and left sides of the patient. The red outlines in panels B and D were added afterward to mark canal location for illustration and were not present on the original diagnostic images.

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