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Prevalence, symmetry and characterization of radicular concavities in human upper premolars

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ABSTRACT

Background: Radicular concavities, particularly in the maxillary premolar region, represent anatomical features that may significantly affect periodontal health. Therefore, the aim of this study was to evaluate the prevalence, dimensions and distribution patterns of radicular grooves in the maxillary premolar region using CBCT.

Methods: In total, 3492 CBCT image datasets from patients treated in all dentistry departments of the University Hospital of Mainz were screened. After applying strict inclusion criteria, a cohort of 836 patients with 1678 maxillary premolars could be included in this study. Horizontal depth, vertical extent, angulation, dentine wall thickness, and the distance from the cemento-enamel junction to the groove origin were analyzed.

Results: Patients with concavities in at least one premolar were identified in 637 of 836 cases (76.2 %). The analyzed first premolars exhibited one or more concavities in 83.7 % (right) and 80.7 % (left) of teeth; second premolars were affected in 37.4 % (right) and 30.0 % (left). Mesial concavities were the most prevalent ($\approx$ 60 %), followed by distal ($\approx$ 35 %) and buccal ($\approx$ 4 %). Mean mesial depth reached 1.09 $\pm$ 0.39 mm and vertical extension frequently exceeded 6 mm. Three concavities in one premolar increased the risk ratio for the contralateral homologue up to 33.33 ($p < 0.001$).

Conclusions: The present study provides a detailed morphological characterization of radicular concavities in maxillary premolars using three-dimensional imaging. These anatomical structures should be considered in clinical decision-making, especially in patients with a predisposition to periodontal disease.

1. Introduction

Dental caries and gingivitis/periodontitis rank among the most common oral diseases in humans (Peres et al., 2019). These diseases are closely linked to the presence of oral biofilm (Belibasakis et al., 2023; Peres et al., 2019; Petersen and Ogawa, 2012). The accumulation of biofilm, especially in subgingival areas, plays a crucial role in the development and progression of periodontal diseases (Tomasi et al., 2023). Moreover, subgingival biofilm is more difficult to control by oral hygiene measures and subgingival instrumentation than supragingival biofilm (Cobb, 2002; Quirynen and Bollen, 1995).

Irregular or rough root surfaces serve as ideal niches for bacterial adhesion and promote biofilm retention and formation (Jepsen et al., 2018; Quirynen and Bollen, 1995). Subgingival bacterial populations grow in anatomical conditions that provide protection from the host's immune response and allow pathogenic microorganisms to proliferate. Consequently, irregularities on the tooth surface such as concavities or grooves create an ideal environment for bacterial colonization (Beycioglu et al., 2024; Jepsen et al., 2018; Zhao et al., 2014) The persistence of pathogenic biofilms in these hard-to-reach areas contributes to the continuous progression of periodontal disease (Beycioglu et al., 2024; Jepsen et al., 2018; Zhao et al., 2014).

Radicular concavities, especially in the maxillary premolar region, are an anatomical variety that can significantly compromise periodontal health. These varieties can restrict mechanical biofilm removal for both patients and dentists, thus increasing the loss of periodontal attachment

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(Beycioglu et al., 2024; Zhao et al., 2014). There are few studies addressing the comprehensive three-dimensional analysis of radicular concavities, especially with regard to cone beam computed tomography (CBCT), which provides high-resolution three-dimensional imaging that can accurately characterize these morphological varieties in vivo (Beycioglu et al., 2024; Fan et al., 2018). A clearer understanding of whether these concavities represent isolated anomalies or follow consistent morphological patterns can help to identify potential risk sites for the onset and progression of periodontal disease.

A detailed morphological characterization of radicular concavities is essential for both preventive strategies and effective periodontal therapy. As concavities and grooves present important anatomical challenges, they can influence periodontal health and disease and even the success of periodontal therapy (Jepsen et al., 2018). Therefore, the aim of this study was to evaluate the prevalence, dimensions and distribution patterns of radicular grooves in the maxillary premolar region using CBCT.

2. Materials and methods

2.1. Characterization and selection of patients

In total, 3492 CBCT image datasets from patients treated in all dentistry departments of the university hospital of Mainz were screened. All CBCT datasets underwent a rigorous evaluation to determine their eligibility for the study. A primary inclusion criterion was the presence of at least one upper premolar on the CBCT scans. Teeth whose roots were not fully developed or could not be clearly identified, e.g. due to apicoectomy or apical resorption, were excluded from the analysis. In addition, datasets in which the cementoenamel junction (CEJ) was not clearly visible due to wedge-shaped defects, restorations or remaining root fragments were not included. Premolars with root caries or severe non-carious defects were also considered non-eligible for the study. To ensure data reliability, datasets with compromised imaging due to restoration and movement artifacts or technical errors were not considered either. Finally, a cohort of 836 patients with 447 women (53 %; mean age: 38.9 ± 16.3 years) and 389 men (47 %; mean age: 39.6 ± 17.4 years) could be included in this study. In these patients, a total of 1678 maxillary premolars were analyzed, including on the right side 442 first premolars (PM1-R) and 366 second premolars (PM2-R), and on the left side 467 first premolars (PM1-L) and 403 second premolars (PM2-L) (Fig. 1).

The study was approved by the local Ethics Committee (Ethik-Kommission Rheinland-Pfalz; 2021–15733-retrospektiv)

2.2. Measurements

The CBCT scans were acquired with the Accuitomo MCT-1 EX-2 F8 ARM system (Morita MFG Corp., Kyoto, Japan). The field of view ranged from 40 × 40 mm to 60 × 60 mm, depending on the clinical indication

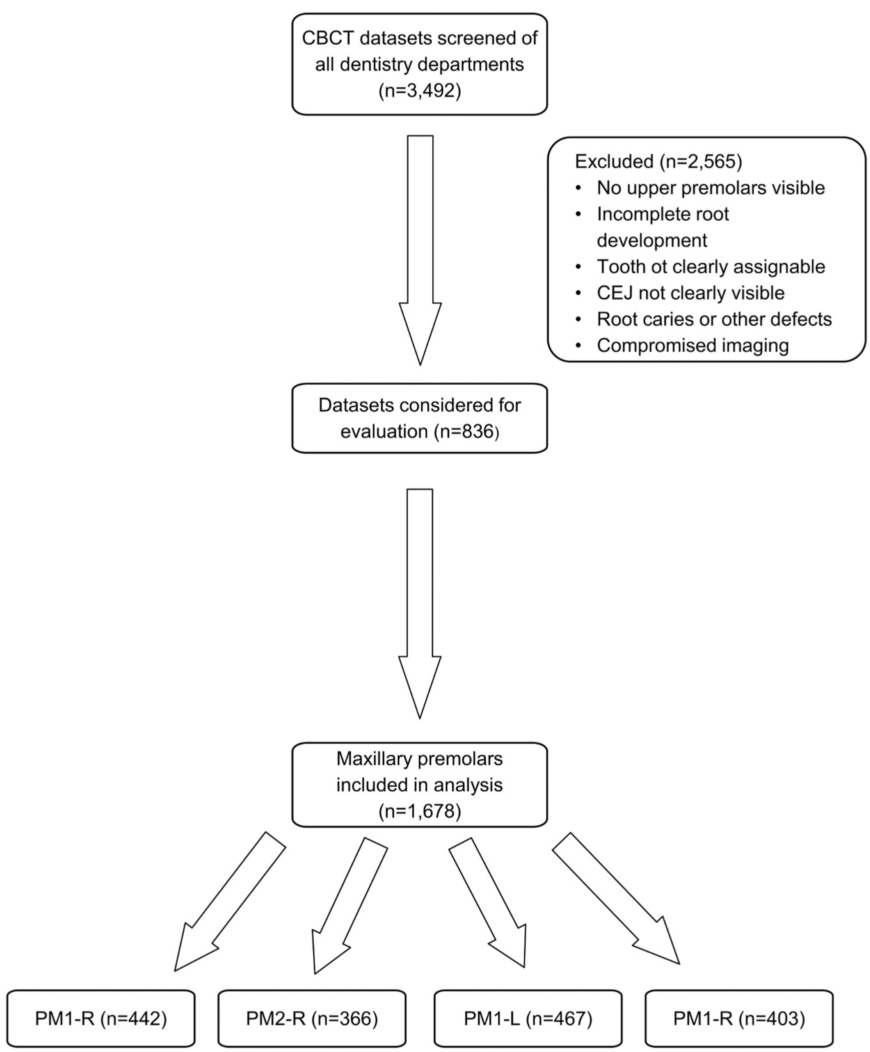

Fig. 1. Study inclusion flow chart.

for imaging. According to the manufacturer, the system offers a consistently high resolution of more than 2 line pairs per millimeter in all image volumes. The imaging parameters included a voltage range of 60–80 kV and a current range of 1–10 mA. The data sets were visualized and analyzed using One Data Viewer Plus software (J. Morita MFG Corp., Kyoto, Japan). This software enabled spatial reconstruction and multiplanar reformatting and facilitated detailed assessment of the radicular furrows by navigation in the axial, sagittal and coronal planes. At first, the frequency of concavities on each maxillary premolar was determined. Additionally, their localization on the root surface was documented and analyzed regarding the co-occurrence of concavities across multiple premolars in each individual patient. The horizontal concavity depth was determined by measuring the distance from the deepest point of the concavity onto an auxiliary tangent drawn through the most prominent edges of the concavity (Fig. 2A). The vertical extent of the concavity was determined by identifying its origin and end points in the axial plane and measuring the distance between them in the coronal plane (Fig. 2B). The concavity angulation was determined by measuring the angle between the auxiliary tangent and the deepest point of the concavity (see Fig. 2C). The minimum dentin wall thickness at the deepest point of the concavity in the axial plane was recorded (Fig. 2D). The cervical origin of the concavity or groove was defined radiographically as the cementoenamel junction (CEJ) or, alternatively, the first notable change in hard tissue thickness, as visible across all planes.

2.3. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (version 27), and data visualizations were generated with GraphPad Prism. Poisson regression analysis was employed to model associations between individual-level variables and count data. To evaluate the co-occurrence of morphological features across premolars at the patient level, Fisher's exact test was applied. Descriptive statistics, including mean values and standard deviations, were calculated. A significance level of α = 0.05 was used for all statistical tests.

3. Results

3.1. Prevalence of radicular concavities

The analyzed PM1-R exhibited radicular concavities with varying frequency in the examined sample (n = 442). A single concavity was present in 47.1 % of these teeth (n = 208), while 32.8 % (n = 145) showed two concavities and 3.8 % (n = 17) exhibited three concavities. In contrast, 16.3 % (n = 72) of the PM1-R had no concavities. In PM2-R (n = 366), the distribution of concavities was as follows: 25.4 % (n = 93) showed a single concavity, 10.6 % (n = 39) two concavities, and 1.4 % (n = 5) three concavities, respectively. A share of 62.6 % (n = 229) of these teeth showed no concavities at all. Of PM1-L (n = 467), in 43.9 % (n = 205) a single concavity, in 33.4 % (n = 156) two concavities and in 3.4 % (n = 16) three concavities were found. No concavities were detected in 19.3 % (n = 90) of the sample. In PM2-L (n = 403), 19.3 % (n = 78) showed a single concavity, 9.7 % (n = 39) showed two concavities and 1 % (n = 4) three concavities, respectively. The majority of 70 % (n = 282) of the PM2-L were free of concavities (Fig. 3).

Regarding the number of concavities per number of roots, we found 61.9 % of single-rooted teeth without concavities, 27.4 % with one, 10.6 % with two and 0.1 % with 3 concavities, respectively. Among the two-rooted teeth, 0.5 % present with 0, 51.4 % with one, 45.3 % with 2 and 2.8 % with three concavities. Three-rooted teeth all exhibit 3 concavities (Fig. 4).

Patients with concavities in at least one premolar were identified in 637 of 836 cases (76.2 %). Of all affected premolars (n = 1678), 856 premolars (51 %) belonged to female patients and 822 premolars (49 %) to male patients, indicating a balanced gender distribution. No

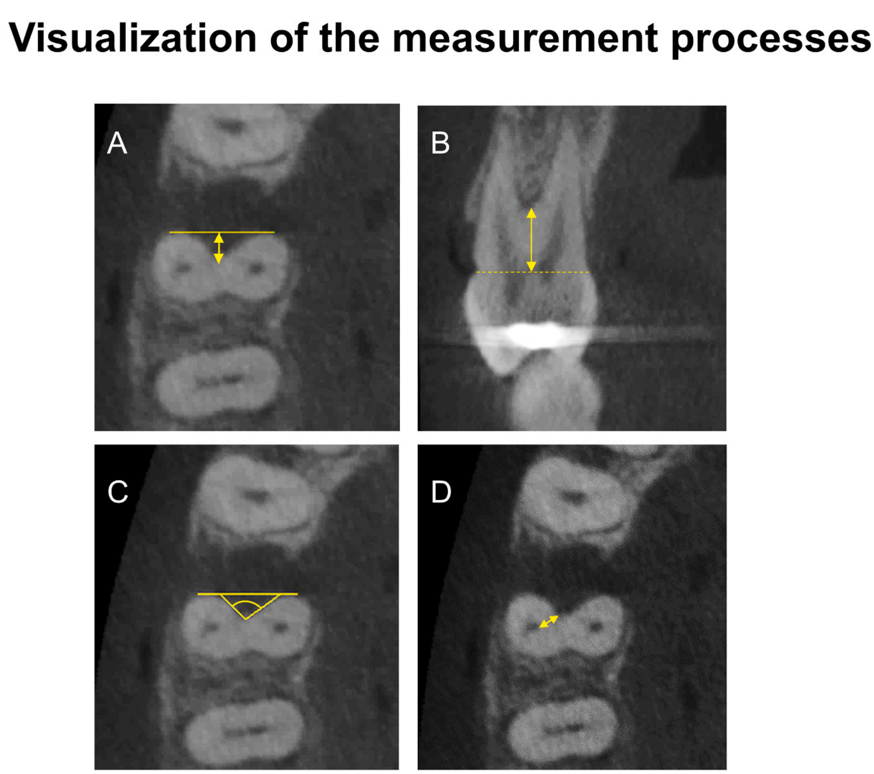

Fig. 2. Measurement procedures on CBCT scans. Representative images illustrating the methods used for measuring radicular concavities. (A) Horizontal concavity depth was measured from the deepest point of the concavity to a tangent connecting the most prominent adjacent surfaces. (B) Vertical extension was assessed between the coronal and apical endpoints of the concavity. (C) The concavity angle was determined between the auxiliary tangent and the deepest point. (D) Minimum dentine wall thickness was measured at the deepest concavity point in the axial plane.

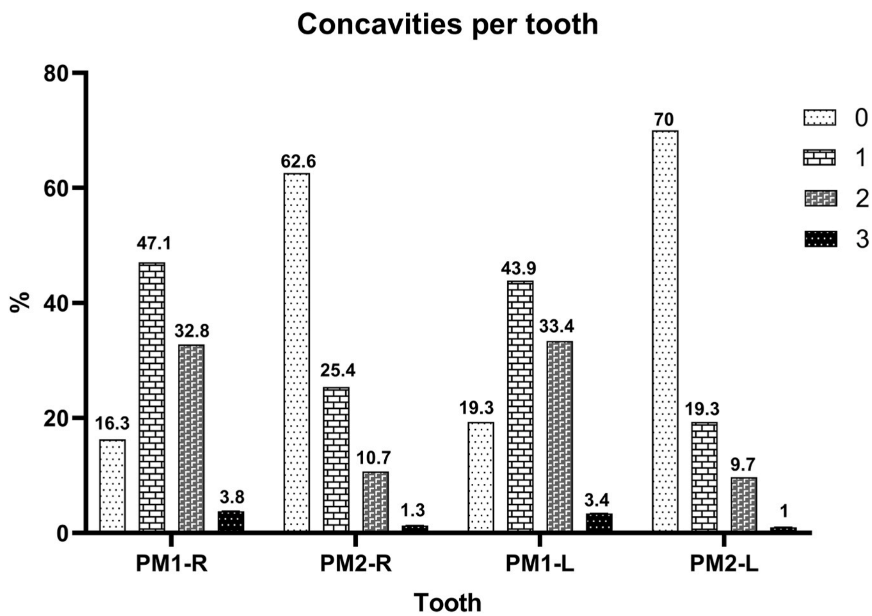

Fig. 3. Number of concavities per tooth. Distribution of maxillary premolars (PM1-R, PM2-R, PM1-L, PM2-L) according to the number of radicular concavities (0–3). Percentages reflect proportions relative to the total number of each tooth type.

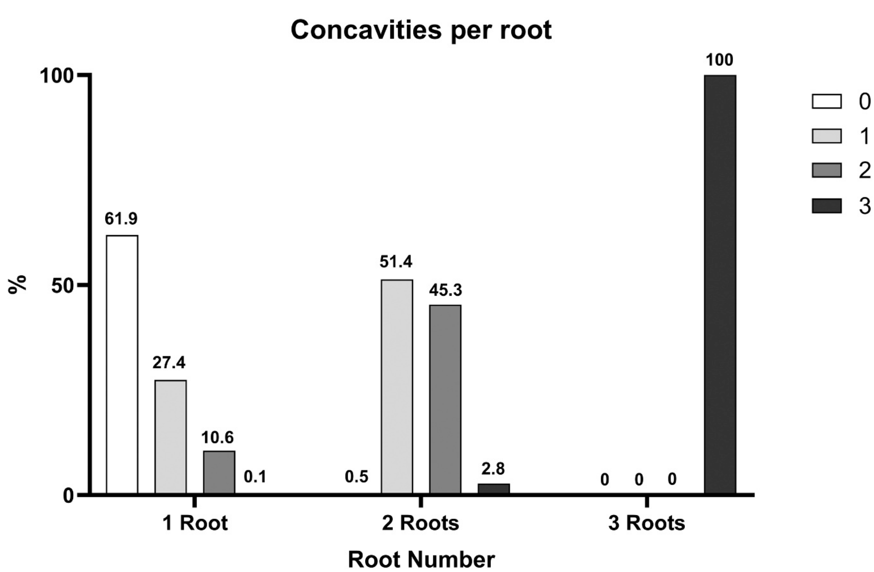

Fig. 4. Number of concavities per root type (%). Frequency of radicular concavities in single-, double- and triple-rooted maxillary premolars. Multirooted teeth showed a higher prevalence of multiple concavities compared to single-rooted counterparts.

significant correlation was found between the number of concavities and gender ($p = 0.508$).

3.2. *Coexistence of concavities among premolars*

The presence of 1–3 concavities in a single premolar was associated with a slightly to moderately increased likelihood of concavities in all other premolars as shown in Table 1. When the analysis was restricted to premolars with three concavities, the probability of concavities occurring in other premolars was even more increased. If a second premolar showed three concavities, the probability, i.e. Risk Ratio for having also three concavities on the contralateral second premolar was particularly strong (Table 1).

Table 1
Co- existence and likelihood of the appearance of concavities on several premolars. * $p < 0.001$.

Paired premolars	Risk ratio	
	Number of concavities = 1–3	Number of concavities = 3
PM1-R/PM2-R	1.13 *	11.89 *
PM1-R/PM1-L	1.11 *	12.47 *
PM1-R/PM2-L	1.17 *	14.49 *
PM2-R/PM1-L	1.24 *	10.00 *
PM2-R/PM2-L	2.18 *	33.33 *
PM1-L/PM2-L	1.21 *	25.00 *

3.3. Localization of concavities

A total of 549 concavities were identified on PM1-R. Among these, mesial concavities were the most prevalent, observed in 345 teeth (62.8 %). Distal concavities were detected in 186 premolars (33.9 %), while buccal concavities were present in only 18 cases (3.3 %). On PM2-R, 186 concavities were recorded. Of these, 60 were mesial (32.3 %), 120 were distal (64.5 %), and 6 were buccal (3.2 %). For PM1-L, a total of 565 concavities were observed. Mesial concavities were present in 338 PM1-L (60 %), distal concavities for 205 PM1-L (36.3 %), and buccal concavities for 21 PM1-L (3.7 %). PM2-L exhibited 168 concavities in total. Mesial concavities were noted in 54 PM2-L (32.1 %), distal in 109 PM2-L (64.9 %), and buccal in 5 PM2-L (3.0 %) (Fig. 5).

While the vast majority of single-rooted teeth had no concavities, multi-rooted teeth almost invariably showed at least one concavity. The distribution was almost equal in the single-rooted teeth; in the multi-rooted teeth, mesial concavities predominated (Fig. 6).

3.4. Horizontal depth of radicular concavities

The horizontal extension, simply referred to as the "depth" of the concavities in PM1-R yielded a mean of 1.08 ± 0.35 mm for the mesial concavities. Distal concavities showed a mean depth 0.97 ± 0.34 mm and on the buccal aspect 1.05 ± 0.38, respectively. For PM2-R, the mean depth of the mesial concavities was 0.88 ± 0.41 mm and 0.91 ± 0.37 mm on the distal aspect, respectively. On the buccal aspect, the concavities revealed a mean depth of 1.19 ± 0.49. For PM1-L, the mesial concavity depth was 1.09 ± 0.39 mm. The distal mean depth was 1.01 ± 0.36 mm and the buccal mean depth was 0.89 ± 0.30 mm, respectively. For PM2-L, the mean of the mesial concavities was 0.78 ± 0.26 mm, while the mean of the distal concavities was 0.92 ± 0.40 mm and 0.92 ± 0.31 mm for the buccal aspect, respectively (Table 2).

3.5. Vertical extension of radicular concavities

The mean vertical extension of the mesial and distal concavities in PM1-R was 6.73 ± 2.63 mm and 5.40 ± 2.75 mm, respectively. The buccal vertical concavity extension was 4.41 ± 1.89 mm. For PM2-R, the mesial extension showed a mean value of 6.09 ± 2.49 mm. The distal concavity extension resulted in a mean of 6.42 ± 2.75 mm. On the buccal aspect, an extension of 6.05 ± 3.67 was found. The analysis of the mesial concavities of PM1-L revealed a mean vertical extension of 7.19 ± 2.68 mm, while the distal concavities showed a mean vertical extension of 5.82 ± 2.77 mm. The vertical extension of the buccal concavities was 4.92 ± 2.17 mm. For PM2-L, the mean mesial concavity extension was 5.80 ± 2.82 mm. The distal vertical concavity extension was 6.52 ± 2.69 mm and the buccal concavity extension was 5.93 ± 2.89 mm, respectively (Table 3).

3.6. Concavity angle

The angle of the mesial concavity of PM1-R was 107.96 ± 23.78°. For the distal concavities, the mean angle was 95.99 ± 25.48° and for the buccal concavities 74.29 ± 25.48°, respectively. For PM2-R, the mean mesial concavity angle was 104.25 ± 28.02°. For the distal and the buccal aspects, the mean angles were 101.88 ± 25.60° and 74.90 ± 20.48°, respectively. For PM1-L, a mesial concavity angle of 106.94 ± 25.30°, a distal angle of 94.31 ± 24.84° and a buccal angle of 78.75 ± 19.11° were found, respectively. For PM2-L, the mesial angle was 108.01 ± 23.04°, the distal angle was 101.19 ± 27.38° and the buccal angle was 81.40 ± 22.00° (Table 4).

3.7. Minimum dentine wall thickness

The mean thickness at the mesial aspect was 1.45 ± 0.29 mm, while the dentin wall thickness at the distal concavity averaged 1.55 ± 0.38 mm and 1.14 ± 0.38 mm at the buccal aspect. For PM2-R, the mesial average dentine thickness was 1.41 ± 0.36 mm, whereas the distal dentin thickness was 1.38 ± 0.35 mm and 0.99 ± 0.15 mm on the buccal aspect. In PM1-L, the dentine thickness at the mesial concavities averaged 1.35 ± 0.30 mm, while the thickness at the distal aspect was 1.53 ± 0.34 mm and 1.01 ± 0.27 mm on the buccal aspect. For PM2-L, the mesial dentin thickness was 1.44 ± 0.37 mm, and the distal concavities showed an identical mean thickness of 1.44 ± 0.37 mm, whereas the buccal dentine thickness was 1.34 ± 0.27 mm (Table 5).

3.8. Distance of concavity origin to CEJ

In PM1-R, the mean distance from the CEJ to the mesial concavity

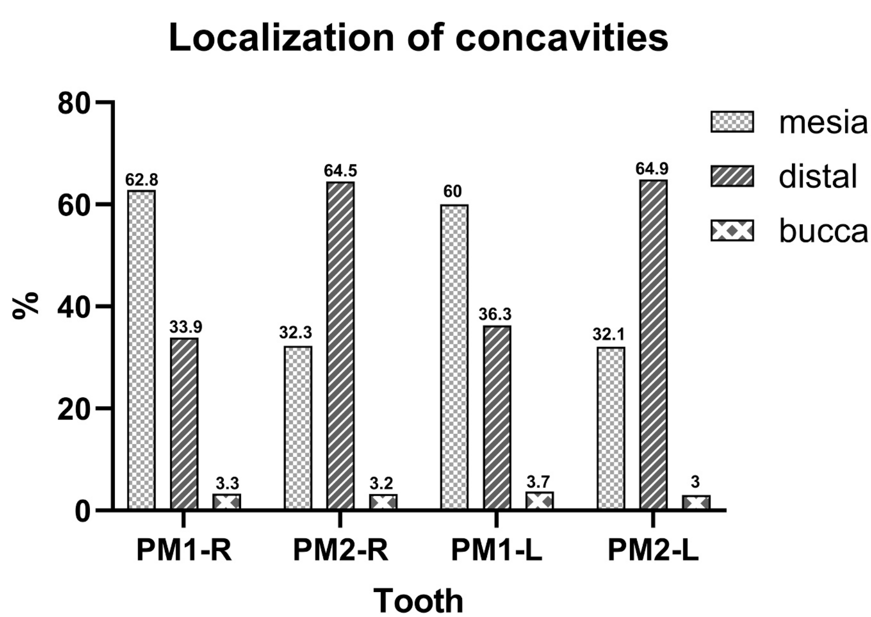

Fig. 5. Localization of radicular concavities. Prevalence of concavities by root surface location (mesial, distal, buccal) in each premolar type. Mesial concavities predominated in first premolars, while distal concavities were more common in second premolars.

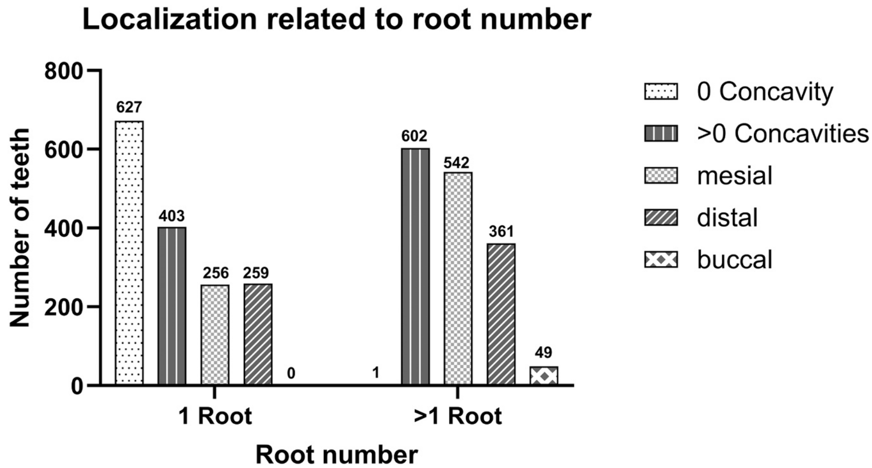

Fig. 6. Localization related to root number. Distribution of concavity locations (mesial, distal, buccal) depending on the number of roots. Multi-rooted premolars showed a higher frequency of mesial concavities than single-rooted teeth.

Table 2
Horizontal depth of concavities (mm). SD: standard deviation.

	Mesial depth	SD	Distal depth	SD	Buccal depth	SD
PM1-R	1.08	0.35	0.97	0.34	1.05	0.38
PM2-R	0.88	0.41	0.91	0.37	1.19	0.49
PM1-L	1.09	0.39	1.01	0.36	0.89	0.3
PM2-L	0.78	0.26	0.92	0.40	0.92	0.31

Mean horizontal depth (in mm) of radicular concavities for mesial, distal and buccal aspects across all maxillary premolars. PM1s exhibited deeper concavities than PM2s overall.

was 0.60 ± 1.08 mm, the distal mean distance was 2.20 ± 1.52 mm, and the buccal concavity measured 1.82 ± 1.52 mm. In PM2-R, the mesial concavity originated 2.56 ± 1.20 mm from the CEJ, while the distal and buccal concavity distance were 2.12 ± 1.60 mm and 2.09 ± 1.43 mm, respectively.

For PM1-L, the mesial concavity had a mean distance of 0.64 ± 1.32 mm from the CEJ. The distal and buccal concavity distances were 2.35 ± 1.56 mm and 2.00 ± 1.00 mm, respectively. In PM2-L, the mesial concavity was located 2.18 ± 1.91 mm from the CEJ, while the distal and buccal concavities showed mean distances of 2.22 ± 1.67 mm and 2.00 ± 0.44 mm, respectively.

Overall, in both PM1-R and PM1-L, the mesial concavity was consistently closer to the CEJ than the distal and buccal concavities, as indicated by the smaller mean distances. A similar trend was observed in the second premolars (PM2-R and PM2-L), although with generally larger distances (Table 6).

4. Discussion

The present study provides a detailed morphological characterization of radicular concavities in maxillary premolars using three-dimensional imaging. The results show significant variations in the prevalence, dimensions and distribution of these anatomical features, which have potential implications for periodontal health and disease progression.

Our results suggest that radicular concavities are common morphological features in maxillary premolars, with a higher prevalence in PM1 compared to PM2. This observation is consistent with previous studies that have emphasized the anatomical complexity of maxillary premolars, particularly their tendency to develop deep concavities and grooves, which may contribute to plaque accumulation and loss of periodontal attachment (Abitbol et al., 1997; Beycioglu et al., 2024; Wyman et al., 1976).

The distinct difference in the frequency of concavities between PM1 and PM2 indicates a different risk of periodontal disease depending on tooth type. In particular, the higher frequency of concavities in PM1 may make these teeth more susceptible to bacterial colonization, supporting the findings that anatomical irregularities may serve as bacterial reservoirs that facilitate periodontal destruction (Beycioglu et al., 2024).

The localization of the concavities seems to play a crucial role in their impact on periodontal health. The data suggest that mesial grooves are more common than distal or buccal grooves, especially in PM1. This finding is consistent with reports suggesting that mesial concavities in maxillary premolars contribute to the complexity of plaque removal, as these surfaces are less accessible to both mechanical and professional cleaning and determine the risk for periodontitis (Abitbol et al., 1997; Jepsen et al., 2018; Wyman et al., 1976). The comparatively high number of concavities on PM1 may be attributed to the anatomical complexity and furcation development typically associated with multi-rooted first premolars.

The vertical and horizontal extent of the concavities also suggests their role in susceptibility to periodontal disease. The frequent vertical extension of these concavities beyond 6 mm highlights the clinical challenge of achieving thorough subgingival biofilm removal. Moreover, the minimum dentine wall thickness indicates significant structural vulnerability of the roots. This anatomical vulnerability may complicate

Table 3
Vertical extension of concavities (mm). SD: standard deviation.

	Mesial extension	SD	Distal extension	SD	Buccal extension	SD
PM1-R	6.73	2.63	5.49	2.75	4.41	1.89
PM2-R	6.09	2.50	6.42	2.75	6.05	3.67
PM1-L	7.20	2.68	5.83	2.68	4.92	2.17
PM2-L	5.80	2.82	6.52	2.69	5.93	2.89

Mean vertical extent (in mm) of concavities from the cemento-enamel junction (CEJ) to the apical limit, per surface and premolar type. The mesial aspect of PM1s showed the greatest vertical reach.

Table 4
Vertical extension of concavities (°). SD: standard deviation.

	Mesial angle	SD	Distal angle	SD	Buccal angle	SD
PM1-R	107.96	23.78	96.00	25.48	74.29	21.04
PM2-R	104.25	28.02	101.88	25.60	74.90	20.48
PM1-L	106.94	25.30	94.31	24.84	78.75	19.11
PM2-L	108.01	23.04	101.19	27.38	81.40	22.00

Average angulation (in degrees) of concavities on each root surface. Mesial concavities consistently displayed wider angles compared to distal and buccal aspects.

Table 5
Minimum dentine wall thickness (mm). SD: standard deviation.

	Mesial thickness	SD	Distal thickness	SD	Buccal thickness	SD
PM1-R	1.44	0.29	1.55	0.38	1.14	0.33
PM2-R	1.41	0.36	1.38	0.35	0.99	0.15
PM1-L	1.35	0.31	1.53	0.34	1.01	0.27
PM2-L	1.44	0.37	1.44	0.37	1.34	0.27

Mean dentine thickness (in mm) at the deepest point of the concavity. Buccal concavities showed the thinnest dentinal walls, suggesting increased structural vulnerability.

subgingival instrumentation and increase the risk of pulpal injury, especially with aggressive debridement techniques (Flemmig et al., 1998a,b; Flemmig et al., 1997).

Understanding the anatomical complexity of radicular concavities is crucial for periodontal prevention and therapy. Given the relationship between the presence of concavities and loss of periodontal attachment, clinicians should consider these features when planning preventive and therapeutic interventions. For example, non-surgical periodontal therapy may be less effective in teeth with deep radicular concavities and grooves due to limited access to instruments for complete removal of subgingival plaque and calculus (Cobb, 2002; Graziani et al., 2017; Jepsen et al., 2018; Rateitschak-Plüss et al., 1992). The remarkably thin dentin wall observed at concavity sites represents a structural risk zone. The findings suggest an elevated risk for endo-perio lesions, i.e., pathological communications between pulp and periodontal tissues, particularly in younger patients with wide dentinal tubules (Papapanou et al., 2018).

Furthermore, the coexistence of concavities on contralateral and adjacent premolars suggests that such teeth may share a common morphological predisposition to periodontal disease. This is supported by our results showing a significant association between the concurrence of concavities in paired premolars, especially between PM2-R and PM2-L ($p < 0.001$). These results suggest that patients with concavities in a premolar might have an increased risk of developing periodontal complications in adjacent teeth, emphasizing the need for a comprehensive periodontal examination in individuals with such anatomical characteristics. By integrating CBCT-based examinations into periodontal diagnostics in certain cases, clinicians can improve early detection and customized treatment planning for individuals at higher risk due to these morphological varieties.

Although this study provides valuable insights into the morphology of radicular concavities, some limitations should be noted. In the present study, no periodontal parameters were measured and therefore, no information about the periodontal destruction and its possible coexistence with the concavities was provided. Future studies including radiological and clinical examinations are therefore needed. Moreover, longitudinal studies are necessary to disclose a causality between concavities and periodontitis. For instance, it has been reported that palatogingival grooves on maxillary incisors extending beyond the coronal third of the root are associated with radiographic bone loss and periapical lesions (Gaudex et al., 2024; Yildirim and Goker Kamali, 2025).

Although gender-related differences in dental root morphology have been discussed in the literature, our Poisson regression analysis revealed no significant difference in the number of radicular concavities between genders ($p = 0.508$). Given this result, we refrained from further stratification by gender. However, future studies with larger and balanced cohorts may further explore possible gender-related anatomical variations.

The Arizona State University Dental Anthropology System (ASUDAS) represents a widely used and standardized method for scoring dental morphological traits, including the presence of longitudinal root grooves in maxillary premolars (Turner et al., 1991). While this approach is highly valuable for anthropological research and cross-population comparisons, it does not encompass radicular concavities as three-dimensional features that can be quantified in terms of depth, width, and symmetry. In the present study, we therefore focused on CBCT-based morphometric analyses, which allow for a detailed and clinically relevant characterization of concavities. Nevertheless, ASUDAS and CBCT-based measurements may be viewed as complementary approaches, and future research could profitably integrate both perspectives to bridge anthropological comparability with clinical applicability.

Future research should also investigate the genetic and developmental factors that contribute to the formation of these varieties to better understand their etiology.

Table 6
Distance of concavity origin from the CEJ (mm). SD: standard deviation.

	Mesial distance	SD	Distal distance	SD	Buccal distance	SD
PM1-R	0.60	1.08	2.20	1.52	1.82	0.81
PM2-R	2.56	2.00	2.13	1.60	2.09	1.43
PM1-L	0.64	1.32	2.35	1.56	2.00	1.00
PM2-L	2.18	1.91	2.22	1.67	2.00	0.44

Mean vertical distance (in mm) from the cemento-enamel junction to the start of the concavity on each root surface. Mesial concavities were generally closer to the CEJ than distal or buccal ones.

5. Conclusion

This study emphasizes the frequency and different distribution patterns of concavities in human premolars. Given their clinical relevance and treatment difficulty, detailed understanding of these anatomical concavities is essential for risk assessment and periodontal therapy planning. The results of the present study suggest that these anatomical structures should be considered in clinical decision-making, especially in patients with a predisposition to periodontal disease.

CRediT authorship contribution statement

Philipp Mildenberger: Writing – review & editing, Software, Methodology, Formal analysis, Data curation. **Pablo Cores Ziskoven:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis. **Jens Weusmann:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Lisann Mäder:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **James Deschner:** Writing – review & editing, Visualization, Supervision, Project administration, Investigation, Formal analysis, Conceptualization.

Ethical statement

Hereby, I, Jens Weusmann, consciously assure that the manuscript "Prevalence, symmetry and characterization of radicular concavities in human upper premolars" has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Mainz, 22.07.2025

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aanat.2025.152746.

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