

Fenestration and dehiscence on CBCT: diagnostic criteria, prevalence, and emerging AI applications – a systematic review and meta-analysis

INPLASY202640056

doi: 10.37766/inplasy2026.4.0056

Received: 16 April 2026

Published: 16 April 2026

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ADMINISTRATIVE INFORMATION**Support** - None.**Review Stage at time of this submission** - Preliminary searches.**Conflicts of interest** - None declared.**INPLASY registration number:** INPLASY202640056**Amendments** - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 16 April 2026 and was last updated on 16 April 2026.**INTRODUCTION**

Review question / Objective This systematic review and meta-analysis aims to address the following objectives regarding alveolar bone fenestration and dehiscence assessed on cone-beam computed tomography (CBCT):

- (1) To synthesize the diagnostic criteria used to define fenestration and dehiscence on CBCT in the published literature.
- (2) To estimate the pooled prevalence of fenestration and dehiscence at both patient-level and tooth-level through meta-analysis of proportions, and to explore sources of between-study heterogeneity through subgroup analyses and meta-regression.
- (3) To summarize the measurement methods, reference landmarks, software tools, and observer reliability reported in CBCT-based assessment of fenestration and dehiscence.
- (4) To describe the current applications, model architectures, and diagnostic performance of artificial intelligence (AI)-based methods for the

automated detection or classification of fenestration and dehiscence on dental imaging.

The review is structured around a PECO framework:

Population – human subjects undergoing CBCT imaging;

Exposure – presence of fenestration or dehiscence on CBCT;

Comparator – subgroups defined by jaw, tooth region, surface, population type, and diagnostic criteria;

Outcome – pooled prevalence estimates, diagnostic criteria, measurement methods, and AI performance metrics.

Condition being studied Alveolar bone fenestration and dehiscence are two common forms of alveolar bone defects that affect the osseous support of teeth. Fenestration is defined as a localized, window-like opening in the cortical bone that exposes the root surface, while the alveolar crest remains intact. Dehiscence is defined as a V-shaped or rectangular defect of the alveolar bone that extends apically from the

alveolar crest, resulting in exposure of the root surface along its coronal portion.

Both conditions are clinically significant in orthodontics, periodontics, and implant dentistry. Undetected fenestration and dehiscence can predispose patients to gingival recession, progressive loss of periodontal attachment, and compromised aesthetic and functional outcomes. In orthodontic practice, the presence of these defects may increase the risk of further bone loss during tooth movement, particularly during labial proclination of incisors or buccal expansion. Cone-beam computed tomography (CBCT) provides three-dimensional visualization of the alveolar bone and is the current reference standard for detecting and quantifying these defects. However, the definitions, measurement methodologies, and reported prevalence of fenestration and dehiscence vary substantially across studies, limiting the clinical interpretability of the existing evidence.

METHODS

Participant or population Human subjects of any age, sex, and ethnicity undergoing cone-beam computed tomography (CBCT) imaging. Subgroups of interest include orthodontic patients, non-orthodontic populations, periodontal patients, and mixed populations. Studies involving animal subjects, dry skulls, or cadavers will be excluded.

Intervention This is not an intervention review. The primary exposure of interest is the presence of alveolar bone fenestration and/or dehiscence as assessed on CBCT. No therapeutic interventions are being evaluated. Diagnostic criteria, measurement methods, and AI-based automated detection approaches will be catalogued and synthesized as methodological exposures.

Comparator No intervention comparator applies. For subgroup and exploratory analyses, between-group comparisons will be made across: (i) maxilla vs mandible; (ii) anterior vs posterior teeth; (iii) labial/buccal vs palatal/lingual surfaces; (iv) orthodontic vs non-orthodontic populations; (v) studies applying different diagnostic criteria (e.g., ≥ 2 mm threshold vs 1/3 root length vs any bone exposure); and (vi) geographic regions.

Study designs to be included Cross-sectional studies, retrospective observational studies, prospective cohort studies, and diagnostic accuracy studies (including AI-based studies) that report prevalence, diagnostic criteria, measurement methods, or automated detection of fenestration and dehiscence on CBCT. Case

reports, case series with fewer than 20 participants, conference abstracts, letters, editorials, and narrative reviews will be excluded.

Eligibility criteria Inclusion criteria:

- (1) Original research reporting one or more of: (a) prevalence of fenestration and/or dehiscence on CBCT, (b) diagnostic criteria for these defects, (c) measurement methodology, or (d) AI-based automated detection;
- (2) Human subjects of any age;
- (3) Cross-sectional, cohort, retrospective observational, or diagnostic accuracy study designs;
- (4) Publications in English.

Exclusion criteria:

- (1) Case reports, case series with fewer than 20 participants, conference abstracts without full text, letters, editorials, narrative reviews;
- (2) Studies on animal subjects, dry skulls, or cadavers (unless included as an explicit subgroup);
- (3) Studies using imaging modalities other than CBCT (e.g., panoramic radiography, periapical radiography, micro-CT);
- (4) Non-English publications;
- (5) Studies without extractable data relevant to the review questions.

Information sources Six electronic databases will serve as the primary information sources: PubMed, Embase, Web of Science, Cochrane Library, Scopus, and Google Scholar. In addition, reference lists of all included studies and relevant systematic reviews will be hand-searched to identify additional eligible publications. Grey literature (conference proceedings, institutional repositories) will not be systematically searched given the focus on peer-reviewed evidence. If full-text articles cannot be retrieved, corresponding authors will be contacted by email (up to two attempts). All search results will be imported into EndNote for deduplication and screening.

Main outcome(s) Primary outcomes:

- (1) Pooled prevalence of fenestration on CBCT at patient-level and tooth-level.
 - (2) Pooled prevalence of dehiscence on CBCT at patient-level and tooth-level.
- Effect measures: prevalence as proportions with 95% confidence intervals.

Additional outcome(s) Secondary outcomes:

- (1) Subgroup-specific prevalence estimates stratified by jaw (maxilla vs mandible), tooth region (anterior vs posterior, and by FDI position where data permit), surface (labial/buccal vs palatal/lingual), population type (orthodontic vs non-

orthodontic), diagnostic criteria, and geographic region;

(2) Moderators of between-study heterogeneity identified through meta-regression;

(3) Qualitative synthesis of diagnostic criteria and measurement methods reported in the literature;

(4) Characteristics and diagnostic performance metrics (accuracy, AUC, F1-score, sensitivity, specificity) of AI-based methods for the automated detection of fenestration and dehiscence.

Quality assessment / Risk of bias analysis The methodological quality of prevalence studies will be assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Studies Reporting Prevalence Data, which comprises 9 items covering sampling frame, participant recruitment, sample size adequacy, description of subjects and setting, coverage of analysis, validity of measurement methods, standardization of measurement, statistical analysis, and response rate.

AI-based diagnostic accuracy studies will be assessed using QUADAS-2, which evaluates four domains (patient selection, index test, reference standard, and flow and timing) for risk of bias, with the first three also evaluated for applicability concerns.

Two reviewers will independently perform the quality assessment. Disagreements will be resolved by discussion or, when necessary, by a third reviewer. Inter-rater reliability will be reported using Cohen's kappa. The overall certainty of evidence for the main quantitative findings will be evaluated using the GRADE approach.

Strategy of data synthesis Quantitative synthesis: Pooled prevalence estimates for fenestration and dehiscence will be calculated at both patient-level and tooth-level using random-effects meta-analysis for proportions. Results will be reported as pooled prevalence with 95% confidence intervals. Between-study heterogeneity will be quantified using Cochran's Q test and the I^2 statistic, with $I^2 > 75\%$ indicating high heterogeneity.

Meta-regression: Random-effects meta-regression will explore sources of heterogeneity, including publication year, sample size, mean age, CBCT voxel size, diagnostic criteria type (categorical), and geographic region.

Publication bias: Funnel plots and Egger's regression test will be used to assess small-study effects and publication bias.

Qualitative synthesis: Diagnostic criteria, measurement methods, and AI applications that cannot be quantitatively synthesized due to heterogeneity will be summarized narratively and presented in structured comparison tables.

Software: All analyses will be conducted in R or STATA software.

Subgroup analysis Pre-specified subgroup analyses will be conducted for both fenestration and dehiscence, and separately for patient-level and tooth-level prevalence where data permit:

(1) Jaw: maxilla vs mandible;

(2) Tooth region: anterior vs posterior; and by specific FDI tooth position where data permit;

(3) Surface: labial/buccal vs palatal/lingual;

(4) Population type: orthodontic vs non-orthodontic vs mixed populations;

(5) Diagnostic criteria: ≥ 2 mm threshold vs 1/3 root length proportional criterion vs any bone exposure vs other criteria;

(6) Geographic region: Asia vs Europe vs Middle East vs Americas vs others.

Subgroup differences will be tested using the Q-test for between-group heterogeneity. Subgroup analyses will be conducted only when at least two studies are available per subgroup to avoid unstable estimates.

Sensitivity analysis Each study will be sequentially excluded and the meta-analysis re-run to assess the influence of individual studies on the pooled prevalence.

Language restriction English only.

Country(ies) involved Hong Kong SAR, China.

Keywords cone-beam computed tomography; CBCT; fenestration; dehiscence; alveolar bone; prevalence; meta-analysis; artificial intelligence; deep learning; orthodontics.

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