INPLASY

Artificial intelligence for automated landmark detection in dentistry: a scoping review protocol of reported accuracy across dental, hard-tissue, and soft-tissue landmarks

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 5 August 2026 and was last updated on 5 August 2026.

INTRODUCTION

Review question / Objective What is the nature, extent, and methodological characteristics of the available evidence on artificial intelligence-based automated or assisted anatomical landmark detection in dentistry and craniofacial imaging, and how does reported detection performance vary across dental, hard-tissue, and soft-tissue landmarks?

The objective of this scoping review is to map the available evidence on artificial intelligence (AI), machine learning (ML), and deep learning (DL) approaches for automated or assisted landmark detection in dentistry; characterize the AI architectures and imaging modalities used; compare reported detection performance across dental, craniofacial hard-tissue, and facial soft-tissue landmarks; describe validation approaches and performance metrics; and identify methodological limitations and gaps requiring further investigation.

PCC framework:
Population/Participants: Human dental and craniofacial imaging datasets or digital models containing anatomical landmarks.
Concept: AI-, ML-, or DL-based automated or assisted anatomical landmark identification/localization and its reported performance.
Context: Dental and craniofacial applications using two-dimensional or three-dimensional imaging, including cephalograms, CBCT, facial imaging/photographs, and digital dental models.

Background Accurate anatomical landmark identification is fundamental to diagnosis, treatment planning, assessment of craniofacial growth, and evaluation of treatment outcomes across several dental disciplines, particularly orthodontics and oral and maxillofacial applications. Conventional manual landmark identification is time-consuming and is subject to intra- and inter-examiner variability caused by anatomical overlap, image quality, landmark definition, and observer interpretation.

Artificial intelligence, particularly machine learning and deep learning, has increasingly been applied to dental and craniofacial imaging. Recent developments involving convolutional neural networks, U-Net-based approaches, heatmap regression, object-detection architectures, and other deep-learning frameworks have enabled increasingly automated localization of anatomical landmarks on two-dimensional and three-dimensional images.

Nevertheless, landmark-detection performance may differ substantially according to anatomical category. Dental landmarks, craniofacial hard-tissue landmarks, and facial soft-tissue landmarks differ in visibility, morphology, anatomical complexity, and susceptibility to image-acquisition conditions. Published studies also vary considerably in imaging modality, AI architecture, datasets, validation approaches, reference standards, and performance metrics. Consequently, the current evidence base is heterogeneous and difficult to compare directly. A scoping review is therefore appropriate to systematically map this rapidly developing field, characterize methodological approaches, and identify areas in which evidence remains limited.

Rationale Existing reviews of artificial intelligence in dentistry and orthodontics have generally examined broad diagnostic applications or have concentrated primarily on conventional cephalometric landmark identification. Consequently, there remains a need to map the evidence across a wider anatomical and technological spectrum, including dental/tooth landmarks, craniofacial hard-tissue landmarks, and facial soft-tissue landmarks evaluated using both two-dimensional and three-dimensional imaging and digital dental models.

A scoping review is particularly appropriate because the evidence base incorporates heterogeneous AI architectures, imaging modalities, anatomical landmark definitions, datasets, validation strategies, reference standards, and performance measures. Mapping these characteristics can clarify which applications have been most extensively investigated, identify areas in which evidence remains sparse, characterize methodological variability, and inform priorities for model development, external validation, standardization, and future clinical translation.

METHODS

Strategy of data synthesis A comprehensive search was planned across PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and IEEE Xplore from database inception to March 2026. Controlled vocabulary, including Medical Subject Headings where applicable, was combined with free-text terms related to artificial intelligence, automated landmark detection, dentistry, and craniofacial imaging. Boolean operators AND and OR were used to combine the principal concepts.

The core search strategy was:

("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning" OR "Convolutional Neural Network" OR "Neural Network") AND ("Landmark Detection" OR "Cephalometric Landmark" OR "Anatomical Landmark" OR "Automatic Landmark Identification") AND ("Dentistry" OR "Orthodontics" OR "Dental Imaging" OR "Cone Beam Computed Tomography" OR "CBCT" OR "Cephalogram" OR "Panoramic Radiograph").

For Scopus, the principal concepts were searched using TITLE-ABS-KEY fields. For Web of Science, topic-field searches (TS) were used. The Google Scholar strategy was based on "Artificial Intelligence" AND ("Landmark Detection" OR "Cephalometric Landmark") AND (Dentistry OR Orthodontics OR CBCT). IEEE Xplore was searched using ("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning") AND ("Landmark Detection" OR "Cephalometric Landmark") AND (Dentistry OR Orthodontics OR CBCT). Search syntax was adapted to the indexing and search functionality of each database.

Reference lists of eligible studies and relevant systematic reviews or meta-analyses were additionally screened to identify potentially eligible sources not retrieved through database searching.

Extracted evidence was planned for descriptive and narrative synthesis. Study characteristics, imaging modalities, landmark categories, AI architectures, validation methods, reference standards, and performance measures were to be mapped and compared. Quantitative results including mean radial error, localization error, successful detection rate, accuracy, and intraclass correlation coefficients were to be summarized descriptively. Statistical meta-analysis was not planned because substantial clinical and methodological heterogeneity was anticipated across imaging modalities, landmark definitions, datasets, AI architectures, validation approaches, reporting thresholds, and outcome measures.

Eligibility criteria Eligibility was defined using the Population–Concept–Context framework.

Population/source of evidence: Primary studies involving human dental or craniofacial imaging datasets or digital models containing dental, tooth, craniofacial hard-tissue, cephalometric, or facial soft-tissue anatomical landmarks.

Concept: Application of artificial intelligence, machine learning, or deep learning for automated or assisted identification, localization, or generation of digital representations of anatomical landmarks. Eligible studies were required to report quantitative measures of landmark-detection performance. Studies comparing AI-based landmark detection with manual or human landmark identification were also eligible.

Context: Dental and craniofacial applications using two-dimensional or three-dimensional imaging or digital models, including lateral or posteroanterior cephalograms, cone-beam computed tomography, CT-derived images, facial imaging/photographs, and digital dental models.

Inclusion criteria: Primary peer-reviewed original research articles published in English; studies evaluating AI, ML, or DL systems for automated or assisted anatomical landmark detection; human dental or craniofacial images or digital models; and reporting quantitative landmark-localization or detection-performance measures.

Exclusion criteria: Reviews, systematic reviews, meta-analyses, conference abstracts, editorials, letters, book chapters, and single case reports; animal studies; in-vitro investigations without relevant human computer-assisted landmark detection; studies limited to image segmentation, disease identification, tooth detection, or classification without anatomical landmark localization; studies that did not employ AI-assisted landmark detection; and studies without relevant quantitative landmark-detection outcomes.

No restriction on publication year was imposed other than the final search date of March 2026.

Source of evidence screening and selection All retrieved records were to be imported into reference-management software and duplicates removed before screening. Study selection followed a two-stage process. First, titles and abstracts were independently screened by two reviewers against the predefined eligibility criteria. Records considered potentially relevant proceeded to full-text assessment. Second, the full texts of potentially eligible studies were independently evaluated by two reviewers.

Disagreements at either screening stage were resolved through discussion and consensus. Where consensus could not be achieved, an independent third reviewer was to adjudicate. Reasons for exclusion at the full-text stage were documented. The complete identification and selection process was planned to be reported using a PRISMA-ScR flow diagram.

Data management Bibliographic records were to be managed using reference-management software, with duplicate records identified and removed before screening. A pilot-tested standardized data-charting form was developed for the review. Two reviewers independently charted data from eligible studies, and discrepancies were resolved through discussion and consensus.

The data-charting framework included study identification and publication year, country, study objective, imaging modality, sample size and dataset characteristics, landmark category, AI model or algorithm, validation method, performance metrics, and key findings relating to landmark-detection performance. Additional relevant variables could be incorporated iteratively when identified during the charting process. Final data were compiled in structured tables to facilitate comparison across studies.

Reporting results / Analysis of the evidence Evidence was planned to be synthesized using descriptive and narrative methods. Study characteristics and methodological approaches were to be summarized across imaging modalities, AI architectures, landmark categories, validation strategies, and outcome measures. Reported performance measures, including mean radial error, localization error, successful detection rate, accuracy, and intraclass correlation coefficients, were to be summarized descriptively.

Comparisons were planned across dental/tooth, craniofacial hard-tissue, and facial soft-tissue landmark categories and across relevant imaging modalities. Potential influences on reported performance, including image quality, anatomical complexity, dataset characteristics, AI architecture, and validation strategy, were also to be examined. Owing to anticipated methodological heterogeneity, statistical pooling or meta-analysis was not planned.

Presentation of the results The source-selection process will be presented using a PRISMA-ScR flow diagram. Characteristics of eligible studies will be summarized in structured tables containing author and publication year, country, study objective, imaging modality, sample size and dataset characteristics, anatomical landmark category, AI model or architecture, validation approach, performance metrics, and principal findings.

Narrative and tabular synthesis will map the use of different AI approaches and imaging modalities and compare patterns of reported performance among dental, craniofacial hard-tissue, and facial soft-tissue landmarks. Additional tables or graphical summaries may be used to highlight methodological heterogeneity, validation approaches, performance measures, and gaps in the evidence base.

Language restriction Yes. Only peer-reviewed studies published in English were eligible.

Country(ies) involved Cambodia, India.

Keywords Artificial intelligence; machine learning; deep learning; landmark detection; cephalometry; CBCT; dentistry; orthodontics; scoping review.

Dissemination plans The completed scoping review will be submitted for publication in a peer-reviewed international dental, orthodontic, or dental-imaging journal. Findings may additionally be disseminated through scientific conferences and academic presentations. Following publication, the INPLASY registration number and DOI will be reported in the final article to provide a permanent link between the retrospectively registered protocol and the completed review.

Contributions of each author

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