



# Validity of Artificial Intelligence Models in Orthodontic Diagnosis: A Systematic Review

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## Abstract

**Objective:** This systematic review aimed to evaluate the validity of artificial intelligence (AI)-based models applied to orthodontic diagnosis. **Materials and Methods:** A comprehensive electronic search was conducted in five databases—PubMed, ScienceDirect, Google Scholar, Web of Science, and the Cochrane Library—using the MeSH terms artificial intelligence, orthodontics, orthodontic diagnosis, neural networks, and machine learning. After applying predefined inclusion and exclusion criteria, nine studies were selected for full-text review and critical appraisal. **Results:** The initial search identified 325 studies related to AI in orthodontic diagnosis, and after screening titles and abstracts, 52 full-text articles were assessed for eligibility, of which eleven met the inclusion criteria. The included studies evaluated various AI algorithms for their diagnostic accuracy and clinical applicability. **Conclusion:** The evidence suggests that AI can enhance diagnostic accuracy and efficiency in orthodontics, offering significant potential to improve diagnosis, decision-making, treatment monitoring, and prediction of treatment outcomes. However, further research with standardized methodologies and larger clinical datasets is needed to validate the reliability and generalizability of AI-based diagnostic models in orthodontic practice.

## Subject Areas

Artificial Intelligence

## Keywords

Artificial Intelligence (AI), Orthodontics, Orthodontic Diagnosis, Neural Networks, Machine Learning

## 1. Introduction

The broad term artificial intelligence (AI) refers to the capability of machines and computer systems to perform tasks that typically require human intelligence [1]. The field of AI focuses on developing intelligent systems that exhibit cognitive functions such as language comprehension, learning, reasoning, and problem-solving [2]. Several subfields of AI have been widely applied in biological and medical diagnostics, including machine learning (ML), artificial neural networks (ANNs), convolutional neural networks (CNNs), and deep learning (DL) [2].

In dentistry, AI has emerged as a powerful tool with applications ranging from administrative tasks—such as scheduling and organizing appointments—to supporting clinical diagnosis and treatment planning. AI systems can perform many tasks in dental practice with greater precision, efficiency, and consistency compared to human performance [2]. With the introduction of digital technologies such as intraoral scanners, cone-beam computed tomography (CBCT), and advanced imaging software, orthodontics has experienced remarkable technological progress [3]. The success of orthodontic treatment largely depends on accurate diagnosis and comprehensive treatment planning, which are traditionally based on the patient's medical and dental records, clinical examination, study models, and cephalometric radiographs [4].

AI technologies can assist orthodontic specialists in various diagnostic and decision-making processes, including cephalometric landmark identification, assessment of the need for orthodontic extractions, evaluation of cervical vertebral maturation, prediction of facial attractiveness following orthognathic surgery, and overall orthodontic treatment planning [5].

The purpose of this systematic review was to evaluate the validity and scope of AI-based models that have been implemented in orthodontic diagnostics.

## 2. Materials and Methods

### 2.1. Protocol and Registration

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [6]. The review protocol was registered on the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) under registration number INPLASY202510024.

The research question was formulated using the Participants, Intervention, Comparison, and Outcome (PICO) framework [7]: “What is the validity of artificial intelligence tools used for orthodontic diagnosis?” (Table 1)

### 2.2. Search Strategy

A literature search was conducted using PubMed, ScienceDirect, Google Scholar, Web of Science, and the Cochrane Library to identify English- and French-language studies published between January 1, 2015, and November 2025 that were relevant to our research question. The search employed the following Boolean

keywords: machine learning, artificial intelligence (AI), neural networks, orthodontics, and orthodontic diagnostics, chosen to accurately reflect the focus of this review.

**Table 1.** PICO elements.

PICO Element	Description
Population	Radiographs, cephalograms, and clinical photographs of patients with dental and maxillofacial conditions
Intervention	AI-based diagnostic models
Comparison	Professional assessments and established diagnostic standards
Outcome	Predictive or measurable parameters, including sensitivity, specificity, and accuracy

The initial search yielded 325 articles. After removing 44 duplicates, 281 articles remained for the selection process, which was conducted in two steps. In the first step, studies were screened based on titles and abstracts. In the second step, the full texts of the remaining articles were examined in detail. The studies were then assessed according to predefined inclusion and exclusion criteria. Included studies involved human participants, were available in full text, and evaluated the impact of AI in orthodontic diagnosis. Both observational studies (case-control and cohort) and interventional studies were considered. Excluded studies were case reports, reviews, animal studies, studies with ineligible outcomes or designs, studies with ineligible populations, or publications in languages other than English or French. Applying these criteria resulted in 11 articles included in the final review.

Data from the selected studies were extracted using a structured table that included authors, year of publication, AI application, results, and conclusions.

### 2.3. Qualitative Assessment of the Included Studies

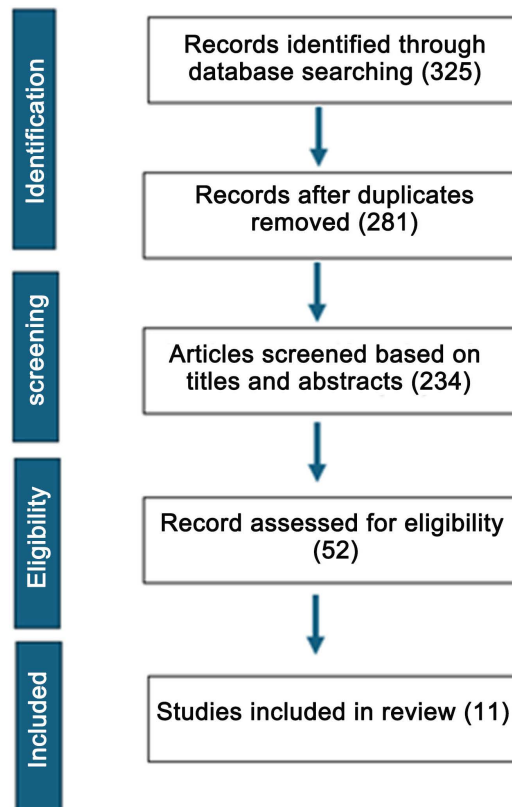
The methodological quality of the included studies was assessed according to the standard criteria described in the Cochrane Handbook for Systematic Reviews [8]. The evaluation parameters included patient randomization, blinding, reporting of withdrawals and dropouts, statistical analysis, sample size calculation, measurement of multiple variables, clearly defined inclusion and exclusion criteria, examiner reliability testing, and transparent reporting of all expected outcomes. Each study was then classified into one of three categories based on the risk of bias: low, medium, or high.

## 3. Results

### 3.1. Search Findings

The initial search using the selected keywords yielded 325 articles. After removing 44 duplicates, 281 articles remained and were screened based on titles and abstracts. This screening step led to the exclusion of 47 articles, resulting in 234 articles retained for further evaluation. Subsequently, 182 articles were excluded af-

ter more detailed assessment, leaving 52 full-text articles for eligibility evaluation. Following full-text review, 38 articles were excluded due to not meeting inclusion criteria. Ultimately, 11 relevant articles were included in the systematic review and analyzed [9]-[19]. **Figure 1** illustrates the PRISMA flow diagram of the literature search and study selection process.



**Figure 1.** PRISMA flow diagram of the study selection process.

### 3.2. Features of the Included Studies

**Table 2** summarizes the general characteristics of the 11 studies included in this systematic review [9]-[19]. The studies comprised retrospective observational studies [9] [11] [16] [17], experimental studies [10] [12], clinical trials [14], clinical studies [13] [15] [18], and a recent systematic review [19], reflecting a diverse range of research designs applied to the evaluation of AI models in orthodontic diagnosis. Data extraction was performed using predefined categories, including author, year of publication, study type, AI application, results, and conclusions.

The included studies primarily focused on the diagnostic performance of AI models in several orthodontic domains, including treatment planning (e.g., extraction decisions) [9] [13] [19], cephalometric landmark identification [15] [16], growth prediction [12] [17] [18], assessment of facial attractiveness in cleft patients [14], and orthognathic surgery planning [11]. Experimental and clinical studies evaluated AI algorithms against human orthodontists' assessments or established diagnostic standards to determine accuracy, reliability, and clinical ap-

plicability [10] [12]-[15] [18]. Retrospective observational studies mainly focused on the predictive capabilities of AI models using historical patient data [9] [11] [16] [17], whereas clinical trials provided real-world validation of AI tools [14]. The systematic review included in 2025 synthesized recent findings on AI-assisted orthodontic extraction planning [19].

**Table 2.** Characteristics and main results of included studies.

Author	Year	Study Type	AI Application	Results	Conclusions
Jung <i>et al.</i> [9]	2016	Retrospective observational study	Diagnosis of extractions with neural network ML	Success rates: 84% for extraction patterns; 93% for extraction vs non-extraction	Neural network AI systems may assist orthodontic extraction decision-making
Thanathornwong <i>et al.</i> [10]	2018	Experimental study	Decision support system for orthodontic treatment need	High agreement with orthodontists (kappa: 1.00 and 0.894)	Bayesian probabilistic model accurately classified treatment need
Choi <i>et al.</i> [11]	2019	Retrospective observational study	Diagnosis of orthognathic surgery	Success rate: 95% - 97% across training, validation, and test sets	Effective for surgery vs non-surgery and extraction decisions
Kok <i>et al.</i> [12]	2019	Experimental study	Identification of growth and development phases via cervical vertebrae	The algorithm ranked second-highest for stage determination stability	AI algorithms can be used diagnostically for growth assessment
Li <i>et al.</i> [13]	2019	Clinical study	Orthodontic treatment planning	94% prediction accuracy for extraction vs non-extraction cases	AI can assist less experienced orthodontists in treatment planning
Patcas <i>et al.</i> [14]	2019	Clinical trial	Facial attractiveness in treated cleft patients	AI ratings (mean: 4.75 ± 1.27) were comparable to human raters; no significant differences	AI can reliably assess facial attractiveness in cleft patients
Hwang <i>et al.</i> [15]	2020	Clinical study	Cephalometric landmark identification	AI detection errors < 0.9 mm vs human examiners	AI performance in landmark recognition comparable to human examiners
Kunz <i>et al.</i> [16]	2020	Retrospective observational study	Cephalometric landmark identification	No significant differences with the human gold standard	AI provides clinically precise automated cephalometric analysis
Wood <i>et al.</i> [17]	2023	Retrospective observational study	Growth and post-pubertal mandibular length prediction	Accuracy: 95.8% - 97.64% mandibular length; 96.6% - 98.34% Y-axis	AI systems accurately predicted mandibular growth and Y-axis growth
Noeldeke <i>et al.</i> [18]	2024	Clinical study	Deep learning for crossbite detection on 2D intraoral photos	Accuracy up to 98.57% for non-crossbite vs crossbite classification	Deep learning models show high potential for detecting malocclusion from 2D photos
Ziaei <i>et al.</i> [19]	2025	Systematic review & meta-analysis	AI in orthodontic extraction treatment planning	Pooled sensitivity 70% (95% CI 61 - 78); specificity 90% (95% CI 87 - 92) across 6261 patients	AI models, especially CNN-based, show promising accuracy in extraction prediction; further validation is needed

### 3.3. Qualitative Synthesis of the Included Studies

The methodological quality of the included studies was evaluated according to the criteria outlined in the Cochrane Handbook for Systematic Reviews [8]. None of the studies reported blinding. Randomization was applied in four studies [10] [12] [13] [16]. Two studies [13] [14] reported dropout rates. Variables were assessed for accuracy in seven studies [9] [10] [13]-[15] [17] [18]. Sample size considerations were mentioned in six studies [9]-[11] [14] [16] [17]. Explicit inclusion and exclusion criteria were described in six studies [9]-[13] [17]. Examiner reliability was assessed in four studies [12] [14]-[16]. All studies pre-specified their outcomes [9]-[19].

Regarding risk of bias, five studies were rated as having a moderate risk [11] [13]-[15] [17], and six studies were rated as having a low risk of bias [9] [10] [12] [16] [18] [19]. **Table 3** presents the quality assessment of the included studies.

**Table 3.** Results of the methodological quality evaluation of the included studies.

Author & Year	Randomization	Blinding	Withdrawal/ Dropout Mentioned	Multiple Measurements of Variables	Sample Size Assessment	Inclusion/ Exclusion Criteria	Examiner Reliability Tested	Expected Outcomes Prespecified	Quality of Study/Bias Risk
Jung <i>et al.</i> (2016) [9]	No	No	No	Yes	Yes	Clear	No	Yes	Low
Thanathornwong <i>et al.</i> (2018) [10]	Yes	No	No	Yes	Yes	Clear	No	Yes	Low
Choi <i>et al.</i> (2019) [11]	No	No	No	No	Yes	Clear	No	Yes	Moderate
Kok <i>et al.</i> (2019) [12]	Yes	No	No	No	No	Clear	Yes	Yes	Low
Li <i>et al.</i> (2019) [13]	Yes	No	Yes	Yes	No	Clear	No	Yes	Moderate
Patcas <i>et al.</i> (2019) [14]	No	No	Yes	Yes	Yes	Unclear	Yes	Yes	Moderate
Hwang <i>et al.</i> (2020) [15]	No	No	No	Yes	No	Unclear	Yes	Yes	Moderate
Kunz <i>et al.</i> (2020) [16]	Yes	No	No	Yes	Yes	Unclear	Yes	Yes	Low
Wood <i>et al.</i> (2023) [17]	No	No	No	Yes	Yes	Clear	No	Yes	Moderate
Noeldeke <i>et al.</i> (2024) [18]	No	No	No	Yes	Yes	Clear	No	Yes	Low
Ziaei <i>et al.</i> (2025) [19]	N/A (Not Applicable)	No	N/A	Yes	Yes	Clear	N/A	Yes	Low

## 4. Discussion

In orthodontics, accurate diagnosis is crucial because it directly influences treatment planning and the resulting clinical outcomes. Recently, there has been growing interest among orthodontists in incorporating AI-based diagnostic tools into

treatment planning [20]. AI models offer the potential to enhance patient care by supporting clinicians in decision-making and improving workflow efficiency, thereby saving time and optimizing clinical care [21]. The primary aim of this systematic review was to evaluate the validity and performance of AI-based models across various orthodontic diagnostic applications.

A key aspect of assessing treatment effectiveness is the evaluation of the patient's facial appearance [21]. AI has shown particular promise in this area. An artificial neural network (ANN) model was developed to predict post-orthognathic surgery facial profiles, demonstrating encouraging results with prediction accuracy exceeding 80% [21]. Similarly, Patcas *et al.* [14] assessed the facial aesthetics of cleft patients using AI, finding that the model's outcomes were comparable to the mean scores assigned by laypeople, orthodontists, and oral surgeons. These findings suggest that AI-based systems can provide objective and reproducible assessments, which may support clinical decision-making and treatment planning [14] [21]. Nonetheless, the authors emphasized that further development is necessary to enhance the predictive accuracy of these systems [14] [21].

Beyond aesthetics, AI is increasingly employed to help practitioners determine the need for orthodontic treatment. In recent years, AI-based clinical decision support systems have been implemented to assist clinicians in making informed choices [22]. For instance, Thanathornwong *et al.* [10] demonstrated that a Bayesian probabilistic model could classify patients accurately into those requiring or not requiring orthodontic treatment, based on intra- and extra-oral data. The Bayesian Network (BN) serves as the foundation for such decision support systems by modeling the causal relationships among multiple factors influencing treatment necessity [10].

Additionally, ANN-based models have been applied to support decisions regarding orthodontic extractions [23]. These systems often rely on template-matching approaches, where the patient's data are compared with a comprehensive reference database to identify similar cases [9] [23]. This allows AI expert systems to simulate the decision-making process of experienced specialists, providing guidance for less experienced clinicians while leaving the final decision to the practitioner [23]. An added advantage of AI is its flexibility; different diagnostic philosophies can be encoded into expert systems, allowing for diverse approaches to treatment planning [9] [23].

When orthodontic treatment is indicated, multiple additional factors must be considered, including the patient's biological maturity [24]. Accurate assessment of biological maturity is critical for timing treatment interventions, particularly in growing patients [12] [17] [24]. In recent years, evaluation of cervical vertebral morphology and development has been considered one of the most reliable methods for assessing skeletal maturity [24]. Uysal *et al.* [25] demonstrated that cervical vertebral stages could be used clinically to estimate growth and development, establishing correlations between chronological age and skeletal age assessed through hand-wrist and cervical vertebral radiographs using Spearman rank-order correla-

tion coefficients. Artificial intelligence has been increasingly applied to facilitate the identification of cervical vertebral growth stages [12]. Kok *et al.* developed an ANN algorithm capable of reliably determining all stages of cervical vertebral maturation, highlighting the potential of AI to provide more precise and unbiased assessments in clinical practice [12]. By reducing subjective variability inherent in human assessment, AI allows for standardized evaluations that may improve treatment planning and outcomes. In addition to skeletal maturity, prediction of mandibular growth is a critical component of orthodontic diagnosis and treatment planning [26]. Mathematical models have been developed to forecast mandibular growth in children based on population growth curves [26]. Buschang *et al.* [26] compared a population-based model with mean annual growth velocities, using multilevel modeling to account for individual and measurement-level differences. Their predictions achieved an accuracy of 76% - 77% for both males and females. More recently, Wood *et al.* [17] applied machine learning techniques to predict post-pubertal mandibular length and Y-axis growth in males, achieving remarkably high accuracy, ranging from 95.80% to 97.64% for mandibular length and 96.60% to 98.34% for Y-axis growth. These findings emphasize that precise prediction of growth patterns can substantially influence treatment strategies for skeletal malocclusions [17]. Clinicians alone may find it challenging to process the extensive data required for such predictions, highlighting the advantage of AI-assisted analysis in handling complex datasets and providing reliable, evidence-based growth forecasts [17].

AI has also demonstrated considerable utility in cephalometric analysis, a cornerstone of orthodontic diagnosis and treatment planning [27]. Accurate identification of cephalometric landmarks underpins measurements of craniofacial angles, distances, and ratios, which in turn guide diagnostic and therapeutic decisions [28]. Traditionally, the quality of cephalometric analyses has depended heavily on the experience of the clinician, leading to variability and potential errors [28]. AI algorithms offer a promising solution by providing automated, reproducible landmark identification [15] [16] [27]. Bourzgui *et al.* [29] developed an automated 3D cephalometric point detection system, achieving a mean error of 2.32 mm across 21 anatomical points using both anatomical and geometric knowledge. Similarly, Kunz *et al.* [16] reported that AI-driven cephalometric analyses demonstrated clinical precision comparable to human examiners across 12 orthodontic parameters, with no statistically significant differences from the gold standard. Hwang *et al.* [15] corroborated these findings, showing that AI systems can match human accuracy in landmark identification. These studies indicate that AI-based methods can serve as reliable adjuncts for repeated analyses, enhancing efficiency and consistency in clinical practice [15] [16] [27]-[29].

Once a diagnosis is established, clinicians must formulate a treatment plan tailored to the patient's needs [18]. In cases where orthodontic treatment alone is insufficient, orthognathic surgery may be required [11]. Optimal outcomes depend on careful preoperative orthodontic preparation to address dental compensations, which maximizes the effectiveness of surgical interventions [30]. Experi-

enced clinicians often draw upon accumulated clinical experience to develop individualized treatment philosophies, which are inherently complex and challenging to transfer to less experienced practitioners within a short period of time [11] [30]. AI offers support in such scenarios by simulating expert decision-making processes [31]. Choi *et al.* [11] developed an AI model capable of making surgery versus non-surgery and extraction decisions. The model demonstrated high predictive performance, with success rates of 95% for the training set, 97% for the validation set, 96% for the test set, and 96% overall for surgery/non-surgery decisions, while correctly predicting the type of surgery in 100% of cases. Such AI tools provide an additional layer of knowledge, particularly in borderline cases, while maintaining clinician oversight and decision-making authority [13].

Integrating AI into treatment planning may therefore enhance decision-making efficiency, support less experienced clinicians, and contribute to improved patient outcomes, while ensuring that human expertise remains central to the management of complex orthodontic and orthognathic cases [11] [13].

## 5. Conclusion

The implementation of artificial intelligence has markedly advanced the precision of diagnostic processes and treatment planning within the medical domain. These systems have demonstrated exceptional efficacy in performing their designated functions. In orthodontics, where clinical decision-making is fundamentally driven by diagnostic assessment, the integration of AI technologies has proven to be both effective and advantageous, contributing to enhanced diagnostic accuracy and more informed therapeutic planning.

## Ethics

This study is a systematic review of previously published studies and did not involve direct research on human participants; therefore, ethics committee approval was not required.

## Authors' Contributions

Both authors contributed equally to all stages of this work, from the study conception and design to data collection, analysis, manuscript drafting, and final approval.

## Conflicts of Interest

The authors declare no conflicts of interest.

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