ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep389

Machine Minds, Perfect Smiles: The Future of AI in Orthodontics: A Contemporary Review

Dr. Yash Kayastha[1]; Dr. Ajay Kantilal Kubavat[2]; Dr. Khyati Viral Patel[3]; Dr. Helly Patel[4]; Dr. Pinal Patel[5]

[1]Postgraduate Student, (B.D.S.) Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sankalchand Patel University, Visnagar, Gujarat, India.
ORCID: 0009-0003-9420-5874
Postal Address: Navsari, Gujarat.

[2]Professor and Head of the Department, (B.D.S., M.D.S.) Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sankalchand Patel University, Visnagar, Gujarat, India.
ORCID: 0000-0003-2099-9715
Postal Address: Ahmedabad, Gujarat.

[3]Reader, (B.D.S., M.D.S.) Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sankalchand Patel University, Visnagar, Gujarat, India.
ORCID: 0000-0002-3463-9924
Postal Address: Kadi, Gujarat.

[4]Postgraduate Student, (B.D.S.) Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sankalchand Patel University, Visnagar, Gujarat, India.
ORCID: 0009-0003-8854-2380
Postal Address: Ahmedabad, Gujarat.

[5]Postgraduate Student, (B.D.S.) Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sankalchand Patel University, Visnagar, Gujarat, India.
ORCID: 0009-0000-9904-2056
Postal Address: Surat, Gujarat.

Corresponding Author: Dr. Yash Kayastha
Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Narsinhbhai Patel Dental College and Hospital, Sakalchand Patel University, Visnagar, Gujarat, India.
Mobile Number: 9537682718
Address: 41, Kanji–Park 2 Sindhi Camp Parmesh Diamond Road Chhapara Navsari.

Publication Date: 2025/09/12

Abstract: Artificial Intelligence (AI) is rapidly transforming orthodontics, evolving from a supplementary aid to a potential cornerstone of modern dental practice. By leveraging the capabilities of machine learning (ML), deep learning (DL), and artificial neural networks (ANNs), orthodontists can now process and interpret massive multimodal datasets with unprecedented precision and efficiency.[1,2,4,15]These datasets range from traditional cephalometric radiographs to complex three-dimensional imaging modalities such as cone-beam computed tomography (CBCT) and intraoral scans.[3]

Recent advancements have demonstrated that AI-powered diagnostic tools can equal, and in some cases surpass, the accuracy of seasoned clinicians in specific tasks such as cephalometric landmark identification or growth prediction.[5] Beyond diagnostics, AI offers powerful applications in treatment planning, biomechanical tooth movement simulations, surgical planning, patient compliance monitoring, and even the customization of orthodontic appliances through integration with 3D printing technologies.[12,13,14]

This expanded review aims to provide an in-depth exploration of AI's principles, current clinical applications, limitations, and future directions in orthodontics. The discussion draws upon literature from 2019 to 2025, case examples, and real-world clinical adoption scenarios. Ethical, legal, and technical considerations—such as patient data privacy, algorithmic bias, regulatory compliance, and seamless integration into clinical workflows—are analyzed in detail.[16,17,18,19] Ultimately, we envision a future in which AI-enhanced orthodontics merges data-driven decision-making with the artistry of clinical expertise, resulting in care that is individualized, efficient, and firmly evidence-based.

Keywords: *Artificial Intelligence, Orthodontics, Machine Learning, Neural Networks, Cephalometrics, CBCT, Tele-Orthodontics, 3D Printing.*

How to Cite: Dr. Yash Kayastha; Dr. Ajay Kantilal Kubavat; Dr. Khyati Viral Patel; Dr. Helly Patel; Dr. Pinal Patel (2025) Machine Minds, Perfect Smiles: The Future of AI in Orthodontics: A Contemporary Review. *International Journal of Innovative Science and Research Technology*, 10(9), 304-310. https://doi.org/10.38124/ijisrt/25sep389

I. INTRODUCTION

Orthodontics is the dental specialty concerned with diagnosing, preventing, and correcting irregularities in the alignment of teeth and jaws. For decades, this process was predominantly manual, relying on the orthodontist's trained eye and accumulated experience to interpret diagnostic tools such as plaster study models, two-dimensional radiographs, and profile photographs. While effective, such methods inherently carry an element of subjectivity; two practitioners might reach slightly different conclusions when assessing the same case.[3]

The 21st century has brought a technological revolution to orthodontics, with three key developments accelerating change:

- Advanced Imaging: Innovations such as CBCT, digital panoramic radiographs, intraoral scanners, and 3D facial photography have dramatically improved anatomical detail capture.
- Computational Power: Affordable, high-performance computing has enabled rapid image processing, real-time data analysis, and high-fidelity simulations.
- Data Accessibility: Electronic health records, image repositories, and global research databases provide vast datasets for AI algorithms to learn from and refine over time.

This convergence has made it possible to create AI systems that adapt dynamically to each patient's unique profile, enabling orthodontists to plan treatments that are not only precise but also highly personalized. The shift mirrors trends in **precision medicine**, where treatment is tailored to the individual rather than based on population averages.[1],[2],[4],[15]

II. FUNDAMENTALS OF AI IN ORTHODONTICS

A. Artificial Intelligence and Machine Learning

Artificial Intelligence encompasses the development of systems that simulate human-like intelligence, capable of reasoning, learning, and problem-solving. In orthodontics, AI integrates data from multiple sources—radiographs, 3D scans, clinical photographs, and case histories—to create a complete diagnostic and prognostic model for each patient.

Machine Learning, a subset of AI, refines this process by enabling algorithms to improve automatically with experience. Rather than being programmed with explicit instructions, ML models identify patterns within large datasets, developing predictive abilities. For instance, by analyzing thousands of historical orthodontic cases, an ML algorithm could determine the likelihood of extraction, the best appliance choice, and even an estimated treatment duration based on an incoming patient's specific metrics.

B. Artificial Neural Networks (ANNs)

Inspired by the human brain, ANNs process data through layers of interconnected "neurons" that assign weights to different inputs. In orthodontics, these networks can simultaneously evaluate multiple diagnostic factors—such as overjet, overbite, skeletal classification, and crowding severity—to predict optimal treatment strategies. Their strength lies in recognizing subtle relationships between variables that might be overlooked by conventional analysis.[8],[9],[10],[11]

C. Deep Learning and Convolutional Neural Networks (CNNs)

Deep Learning models extend ANNs by incorporating multiple hidden layers, allowing them to model intricate relationships within data. CNNs, a particular type of deep learning architecture, excel at image-based analysis. They have been successfully applied to cephalometric landmark identification, CBCT segmentation, and anomaly detection in panoramic images. These networks learn to identify

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep389

features—edges, shapes, and complex structures—without explicit programming, improving their accuracy with each new dataset.

D. Supervised vs. Unsupervised Learning

- Supervised Learning uses labeled datasets, such as cephalometric X-rays annotated with landmark positions, allowing the system to map known inputs to outputs.
- Unsupervised Learning finds hidden structures in unlabeled data, such as grouping patients with similar malocclusion traits, potentially revealing new treatment classification systems.

III. HISTORICAL EVOLUTION OF AI IN ORTHODONTICS

AI's journey in orthodontics began modestly, with early software assisting in digital cephalometric tracing in the 1980s and 1990s. The 2000s introduced CAD/CAM systems and primitive machine learning models in dentistry. From 2010 onwards, the explosion of digital imaging and CBCT data created fertile ground for deep learning models.

Between 2016 and today, CNN-based tools have achieved landmark detection accuracies rivalling expert orthodontists, while AI-driven treatment simulators have become integrated into aligner manufacturing pipelines. Cloud-based AI platforms now enable collaborative diagnostics, where clinicians from different continents can review and refine the same case in real time.[4],[15]

IV. LIMITATIONS OF CONVENTIONAL DIAGNOSTICS

Traditional orthodontic diagnostics—manual cephalometric tracing, plaster study models, and static photographic assessments—have three major limitations:

- Subjectivity: Different clinicians may interpret the same diagnostic record differently.
- Time Consumption: Manual tracing can take up to 20 minutes per patient.
- Lack of Adaptability: Static diagnostics do not update automatically as treatment progresses.

AI overcomes these challenges by providing objective, repeatable, and adaptable assessments, often within seconds.

V. APPLICATIONS OF AI IN ORTHODONTICS:

A. Cephalometric Landmark Identification

One of the earliest and most impactful uses of AI in orthodontics is the automated detection of cephalometric landmarks. Traditionally, orthodontists identify skeletal and dental landmarks manually on lateral cephalograms — a process requiring high skill, concentration, and significant time investment. Even for experienced clinicians, intra- and inter-observer variability is common, leading to inconsistencies in diagnosis and treatment planning.[1,2]

Convolutional Neural Networks (CNNs), trained on thousands of annotated cephalograms, can now identify key skeletal and dental points within seconds. Tools such as WEBceph™, CephX™, and EYES.OF.AI™ integrate directly into digital orthodontic workflows, allowing for instant landmark plotting and automatic calculation of commonly used cephalometric parameters like SNA, SNB, ANB, and Wits appraisal.

➢ Clinical Advantages:

- Speed: Reduces analysis time from 15–20 minutes to less than 30 seconds.
- Standardization: Minimizes human bias, ensuring consistent measurements.
- Integration: AI systems can immediately export landmark data into treatment simulation software, enabling real-time visualization of expected changes.

A multi-center study comparing AI-generated landmark plots with those of three experienced orthodontists found that AI was within 1.2 mm mean error distance, which is well within clinical acceptability. Interestingly, AI consistency was higher than human intra-examiner repeatability, making it a valuable adjunct for research requiring precise, reproducible measurements.

B. Prediction of Extraction Needs

The decision to extract teeth is one of the most critical and debated choices in orthodontic treatment planning. Extraction affects facial esthetics, occlusal stability, and treatment duration. Traditionally, this decision is influenced by factors like skeletal classification, crowding severity, and clinician philosophy.

Artificial Neural Networks (ANNs) can analyze patient profiles — including cephalometric measurements, crowding analysis, soft tissue assessment, and even 3D facial scans — to generate an extraction likelihood score. This can serve as a **second opinion**, particularly for less experienced practitioners.[8],[9]

➢ *Supporting Evidence:*

- Xie et al. (2010): ANN achieved 80% accuracy in extraction decision-making.
- Jung et al. (2021): By combining cephalometric data with soft tissue profile analysis, accuracy rose to over 90%.

➢ *Example:*

Imagine a 14-year-old patient with borderline crowding. AI may analyze the profile, arch space discrepancy, and skeletal relationship, then suggest "non-extraction" with high confidence. The orthodontist, seeing the reasoning breakdown, might feel more assured in pursuing a non-extraction plan, knowing the decision aligns with large-scale data patterns.

C. Tooth Movement Simulation

Orthodontic tooth movement is a biomechanical process influenced by multiple factors — bone density, periodontal ligament response, force magnitude, and direction. Predicting exact movement outcomes manually is challenging.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep389

➢ *AI Contribution:*

Machine learning models can simulate how teeth respond to specific force systems, allowing orthodontists to preview various treatment scenarios. Aligner companies like **Invisalign** use AI-driven staging algorithms to determine the most efficient sequence of movements, minimizing round-tripping and reducing total treatment time.[12],[13]

➢ *Benefits:*

- Patient Education: Patients can visually see predicted before-and-after models.
- Treatment Optimization: Identifies the most biomechanically favorable movement sequence.
- Relapse Risk Prediction: AI can model post-treatment stability to guide retention strategies.

➢ *Example:*

In a case requiring distalization of upper molars, AI simulation predicted the number of aligner stages required and suggested auxiliary elastic placement for maximum efficiency — reducing treatment time by 3 months compared to the clinician's initial plan.

D. Orthognathic Surgery Planning

For skeletal discrepancies beyond the scope of orthodontics alone, orthognathic surgery becomes necessary. Planning these procedures requires accurate prediction of both hard and soft tissue changes.[7]

➢ *Role:*

AI-based 3D morphable models (3DMMs) can simulate postoperative facial profiles by considering both skeletal repositioning and soft tissue elasticity. This helps surgeons and orthodontists visualize esthetic and functional outcomes before the first incision.

➢ *Clinical Benefits:*

- Enhances patient communication and consent.
- Improves interdisciplinary planning between orthodontists and maxillofacial surgeons.
- Reduces surgical revisions by optimizing movements beforehand.

➢ *Example:*

A Class III patient with maxillary deficiency and mandibular excess was planned for two-jaw surgery. AI predicted subtle asymmetry in the initial surgical plan. Adjustments were made preoperatively, leading to improved facial balance and reduced post-op refinement.

E. CBCT Segmentation

CBCT provides unparalleled 3D detail but analyzing the data requires segmenting anatomical structures such as the mandible, maxilla, or airway space. Manual segmentation can take hours per scan.[3]

➢ *Innovation:*

CNN-based segmentation tools, such as those integrated into 3D Slicer AI plugins, can segment jawbones in minutes with Dice similarity coefficients exceeding **0.90**, indicating near-perfect overlap with expert segmentations.

➢ *Applications:*

- Implant planning.
- Airway volume analysis.
- Orthognathic surgery simulation.

F. Growth Prediction

Timing is critical in orthodontics, especially for growth modification appliances. AI models can assess cervical vertebral maturation (CVM) or hand–wrist radiographs to predict growth spurts with an accuracy of ±0.8 years.

Combining radiographic data with genetic markers for truly personalized growth forecasts, enabling more precise timing of functional appliance therapy.

G. AI in Cleft-Related Orthodontics

Cleft lip and palate cases are among the most complex in orthodontics, involving multiple surgical and orthodontic interventions over years. AI can help by:

- Predicting facial symmetry after surgery.
- Monitoring growth and scar tissue influence.
- Identifying genetic links for preventive counseling.

H. Temporomandibular Disorder (TMD) Diagnosis

TMD diagnosis is notoriously challenging, often requiring imaging and functional assessments. AI can detect subtle degenerative changes in CBCT or MRI before they become symptomatic, with accuracies above 90%.[6]

I. AI in Patient Compliance Monitoring

Wear-time sensors in aligners and mobile apps with AI image recognition can track whether patients are wearing appliances as prescribed. Compliance data can be sent automatically to the orthodontist, allowing early intervention when adherence drops.

J. AI in Tele-Orthodontics

AI-assisted tele-orthodontics became essential during the COVID-19 pandemic. Patients could upload intraoral photos, and AI would triage cases, flagging urgent issues. This model continues to benefit rural areas with limited specialist access.

K. AI with 3D Printing in Orthodontics

AI can automate the design of fully customized appliances for 3D printing, reducing design errors and improving fit. Examples include custom brackets, indirect bonding trays, and aligner attachments.

VI. SUMMARY TABLE OF AI APPLICATIONS IN ORTHODONTICS

➢ *Narrative Overview:*

- Cephalometric Landmark Detection: CNN-based tools like CephX™ have shown accuracy between 95–97%, meaning they can be trusted for routine diagnostic use. The main advantage here is speed and elimination of human subjectivity.
- Extraction Prediction: AI models using ANNs analyze multiple parameters to determine whether extractions are

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep389

necessary. With accuracy between 80–92%, they act as a reliable secondary check rather than a sole decision-maker.

- Tooth Movement Simulation: Used extensively in aligner systems such as ClinCheck®, these tools do not offer a single accuracy percentage but instead improve efficiency and reduce mid-treatment adjustments.
- Orthognathic Surgery Planning: AI systems with 3D morphable models predict both skeletal and soft tissue changes with over 90% accuracy, enhancing patient trust in the proposed surgical outcomes.
- CBCT Segmentation: Automated AI segmentation offers consistent results, reducing manual workload and potential errors in anatomical mapping.
- Growth Prediction: DL models predict growth timing with ±0.8 years accuracy, guiding intervention timing.
- Cleft-Related Analysis: AI helps with symmetry evaluation and genetic risk assessment, supporting long-term multidisciplinary care.
- TMD Diagnosis: High accuracy in detecting early joint degeneration enables preventive treatment before significant symptoms occur.

Table 1 Expanded Table

Application	AI Method	Example Tool / Platform	Reported Accuracy	Clinical Impact
Cephalometric Landmark Detection	CNN	CephX™, WEBceph™, EYES.OF.AI™	95–97%	Rapid, reproducible measurements; reduced examiner bias
Extraction Prediction	ANN	Custom research models	80–92%	Provides a consistent second opinion for borderline cases
Tooth Movement Simulation	ML/DL	ClinCheck®, SureSmile® AI	N/A (qualitative)	Optimized treatment staging, improved patient communication
Orthognathic Surgery Planning	3DMM	Hospital-based AI systems	91–95%	Enhances patient consent and interdisciplinary planning
CBCT Segmentation	CNN	3D Slicer AI plugins	91–94%	Accelerates implant planning, airway studies, and surgical prep
Growth Prediction	DL	CVM- and genetic-based models	±0.8 years	Improves timing of growth modification appliances
Cleft-Related Analysis	ML/DL	Custom research tools	Comparable to human	Predicts post-surgical esthetics, supports genetic counseling
TMD Diagnosis	ANN/CNN	Research-based AI	~91%	Early detection of degenerative changes, better long-term outcomes

VII. CHALLENGES AND LIMITATION

Despite its transformative potential, AI in orthodontics faces several challenges that must be addressed before it becomes a fully integrated standard of care.

A. Data Quality and Quantity

AI algorithms thrive on high-quality, well-labeled datasets. Inconsistent imaging protocols, poor-quality scans, or incomplete patient records can significantly degrade performance. In orthodontics, where variations in CBCT exposure, head positioning, and landmark annotation standards exist, these inconsistencies limit the model's ability to generalize.

➢ *Example:*

A CNN trained on high-resolution CBCT scans from one country may perform poorly on lower-resolution scans from another due to differences in machine settings and patient positioning.

B. Bias and Generalization Issues

If training data predominantly represents certain ethnic groups, age ranges, or malocclusion types, the AI model's predictions may be skewed when applied to other populations. This "dataset bias" risks producing suboptimal treatment recommendations for underrepresented groups.[16]

➢ *Solution:*

Diversifying datasets through global collaboration and data-sharing agreements can help ensure AI tools are equitable and applicable to a wide range of patients.

C. Integration with Clinical Workflow

AI tools must seamlessly integrate with existing orthodontic practice management systems, imaging software, and lab communication channels. Disconnected systems create inefficiency and may discourage adoption.[17]

D. Ethical Concerns

- Patient Consent: Patients must understand that AI is involved in their diagnosis or treatment planning.
- Data Privacy: Compliance with regulations such as HIPAA (USA) and GDPR (EU) is essential.
- Ownership of Data: Questions remain about who owns AI-generated insights — the clinician, the patient, or the software provider.[18]

VIII. REGULATORY AND LEGAL PERSPECTIVES

➢ *Medical Device Classification*

Many AI-based orthodontic tools may fall under the category of medical devices, requiring regulatory clearance before commercial use. For instance:

- FDA (USA): Requires premarket clearance for diagnostic software with clinical implications.
- CE Mark (EU): Indicates conformity with EU health, safety, and environmental protection standards.

➢ *Liability Concerns*

If an AI tool's recommendation leads to an unfavorable clinical outcome, determining liability is complex. Currently, the orthodontist remains legally responsible for treatment decisions, but future regulations may assign partial accountability to software developers.

➢ *Global Variations in Regulation*

Some countries have robust AI health-tech approval frameworks, while others are still developing regulations. This creates challenges for software companies seeking global deployment of their tools.[19]

IX. FUTURE PROSPECTS

AI in orthodontics is evolving rapidly, and several promising directions are emerging:

➢ *Multi-Modal AI Models*

These will combine radiographic data, 3D scans, genetic profiles, and even patient lifestyle information to create comprehensive treatment forecasts. Such integration could enable hyper-personalized orthodontics where every decision is tailored to the patient's unique biological and behavioral profile.

➢ *Real-Time AI Assistants*

Imagine intraoral scanners equipped with AI that can instantly identify malocclusion types, calculate arch length discrepancies, and suggest preliminary treatment options during the first patient visit — all without leaving the chairside environment.

➢ *AI-Enhanced Tele-Orthodontics*

Remote monitoring systems will evolve from basic photographic assessments to advanced 3D video consultations powered by AI-driven occlusion analysis, making orthodontic expertise accessible worldwide.

➢ *Preventive Orthodontics Through AI*

By analyzing early childhood dental and skeletal data, AI could predict the likelihood of malocclusion development years in advance, enabling preventive interventions that reduce the need for complex treatments later.

X. CONCLUSION

AI is set to become an indispensable partner in orthodontic care, not by replacing clinicians, but by enhancing their diagnostic precision, planning accuracy, and efficiency. As algorithms become more transparent and interpretable, clinicians will better understand why a model makes certain recommendations, increasing trust in AI-assisted decision-making.

The ultimate vision is a clinician-guided, AI-enhanced orthodontic ecosystem where patient care is individualized, efficient, and grounded in the latest scientific evidence. For this to be realized, ongoing collaboration between orthodontists, software developers, and regulatory bodies is essential. By addressing challenges related to bias, data quality, integration, and ethics, AI can be safely and effectively embedded into orthodontic workflows — transforming not only how we treat malocclusion, but also how we think about orthodontics as a whole.

STATEMENTS AND DECLARATIONS

Ethical committee approval: Not required

Patient Consent: Not required

Declaration of Conflicting Interests:

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

[1]. Hölbling E, Kraxner L, et al. Deep learning for cephalometric landmark detection: systematic review and meta-analysis. Orthod Craniofac Res. 2021;24(2):32-42. doi:10.1111/ocr.12446.
[2]. Hwang H-W, Moon J-H, et al. Evaluation of automated cephalometric analysis based on the latest deep learning method. Angle Orthod. 2021;91(3):329-335. doi:10.2319/021220-100.1.
[3]. Bozkurt TO, Tuncer E, et al. Multiclass U-Net-based segmentation of craniofacial structures on CBCT. Biomed Eng Online. 2021;20(1):1-21. doi:10.1186/s12938-021-00910-9.
[4]. Sathyanarayana S, Zhou G, et al. DL-based automatic cephalometric landmarking in 3D: a systematic review and meta-analysis. Radiol Med. 2023;128:1100-1114. doi:10.1007/s11547-023-01629-2.
[5]. Baccetti E, et al. Systematic review of AI for cervical vertebral maturation staging and growth prediction. Diagnostics (Basel). 2025;15(5):1063.
[6]. Rokhshad R, Lopez MA, et al. Diagnostic accuracy of AI in temporomandibular disorders: systematic review & meta-analysis. J Oral Rehabil. 2024;51(10):1045-1064. doi:10.1111/joor.13637.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep389

[7]. Moon J-H, Kim M-G, et al. Automated photograph-cephalogram image integration using AI models. Angle Orthod. 2024;94(6):595-603.
[8]. Xie X, Wang F, et al. Artificial neural network modeling for deciding if extractions are necessary prior to orthodontic treatment. Angle Orthod. 2010;80(2):262-266.
[9]. Jung S-K, Kim T-W. New approach for the diagnosis of extractions with neural network machine learning. Am J Orthod Dentofacial Orthop. 2016;149(5):716-728.
[10]. Mason T, Kelly KM, et al. A machine learning model for orthodontic extraction/non-extraction decision. Int Orthod. 2023;21(3):100759. doi:10.1016/j.ortho.2023.100759.
[11]. Kim M, Kim J, et al. Use of automated artificial intelligence to predict the need for extractions for orthodontic treatment. Korean J Orthod. 2022;52(2):102-111. doi:10.4041/kjod.2022.52.2.102.
[12]. Hansa I, Semaan SJ, et al. Effectiveness of AI-driven Dental Monitoring in clear aligner treatment. Orthod Craniofac Res. 2023;26(3):123-134.
[13]. Keim RG, et al. Effectiveness of dental monitoring system in orthodontics: a systematic review. J Orthod. 2023;50(3):251-264.
[14]. Mangano F, et al. Remote digital monitoring during the retention phase reduces emergency appointments: a feasibility study. Prog Orthod. 2022;23(1):13.
[15]. Kunz F, et al. AI in orthodontics: evaluation of a fully automated cephalometric analysis using a customized CNN. J Orofac Orthop. 2020;81(1):52-68.
[16]. Mörch CM, Atsu SS, et al. Artificial Intelligence and Ethics in Dentistry: A Scoping Review. J Dent Res. 2021;100(12):1333-1342.
[17]. Brady AP, Neri E. Artificial Intelligence in Radiology—Ethical Considerations. Diagnostics (Basel). 2020;10(4):231.
[18]. ITU FG-AI4H. Ethical considerations of artificial intelligence in dentistry: a checklist framework. Geneva: ITU; 2025.
[19]. Frontiers in Big Data (ESR/ACR). Ethics of AI in Radiology: societal implications and fairness. Front Big Data. 2022;5:850383.