

Literature Review

## Integration of Artificial Intelligence Technology in Orthodontics: Legal and Ethical Aspects

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Received date: July 11, 2024

Accepted date: August 21, 2025

Published date: April 30, 2026

### KEYWORDS

Artificial Intelligence (AI),  
orthodontics, legal, ethical  
aspect.



DOI: [10.46862/interdental.v22i1.9550](https://doi.org/10.46862/interdental.v22i1.9550)

### ABSTRACT

**Introduction:** Artificial Intelligence integration in orthodontics enhances diagnostic accuracy, treatment planning, and clinical efficiency. However, it presents legal and ethical challenges, such as liability, data privacy, and equitable access, necessitating the responsible adoption of AI in clinical practice. This literature review aims to explore the integration of AI technology in orthodontics, with a specific focus on the associated legal and ethical aspects.

**Review:** The review aims to identify the benefits of AI in enhancing orthodontic care, examine the potential legal liabilities and regulatory considerations related to its use, and analyse the ethical implications of AI in patient data management and treatment decision-making. By providing a comprehensive overview, this study intends to highlight the importance of establishing clear guidelines and standards to ensure the safe and ethical use of AI in orthodontics. This literature review synthesizes recent research on the implementation of AI technologies in orthodontics. Studies have demonstrated that AI can process vast amounts of data quickly and accurately, thereby improving diagnostic precision and optimising treatment plans. Nonetheless, the rapid adoption of AI raises concerns about data privacy, legal liability, and equitable access to technology, which are crucial to address for the ethical integration of AI in healthcare.

**Conclusion:** AI integration in orthodontics offers benefits like improved diagnostics and personalized treatment plans, but requires careful legal and ethical considerations.

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**How to cite this article:** Fauziah YA, Narmada IB, Siswantoro ER, Raditya R. Integration of Artificial Intelligence Technology in Orthodontics: Legal and Ethical Aspects. *Interdental Jurnal Kedokteran Gigi*. 2022;22(1):110-118. doi: [10.46862/interdental.v22i1.9550](https://doi.org/10.46862/interdental.v22i1.9550)

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## INTRODUCTION

Technological advancements in the 21st century have brought significant changes across various fields, including dentistry. One of the rapidly evolving technologies is Artificial Intelligence (AI), which has immense potential to revolutionise diagnosis, treatment planning, and patient management in the field of orthodontics. AI offers the capability to analyze data quickly and accurately, reduce human error, and enhance clinical efficiency. However, the implementation of AI in orthodontics also raises several legal and ethical issues that need to be carefully addressed. This article aims to explore the integration of AI technology in orthodontics from both legal and ethical perspectives, highlighting the potential benefits and challenges that may be faced.<sup>1</sup>

Artificial Intelligence has begun to be applied in various aspects of dentistry, including diagnosis and treatment planning in orthodontics. AI technology can be used to analyse radiographic images, predict tooth and jaw growth, and design personalised orthodontic appliances. The ability of AI to process large amounts of data quickly and accurately makes it a valuable tool in clinical practice. However, this development also raises questions regarding the reliability, safety, and legal accountability of using such technology.<sup>2</sup> The integration of AI in orthodontics offers significant benefits. AI can aid in the early detection of dental issues, design more precise treatments, and enhance treatment outcomes. Additionally, AI can reduce the time needed for diagnosis and treatment planning, ultimately improving clinical efficiency and patient experience. The ability of AI to learn and adapt from new data also allows continuous improvement in the accuracy and effectiveness of orthodontic treatments.<sup>3</sup> Besides legal

challenges, the use of AI in orthodontics also raises various ethical issues. One major issue is patient data privacy and security. AI requires large amounts of data to learn and make predictions, which means patient data must be collected and stored. Furthermore, concerns exist about transparency in AI decision-making and how to ensure that AI is used fairly and non-discriminatorily.<sup>4</sup>

Despite its apparent benefits, implementing AI in orthodontics presents complex legal challenges. One of the primary issues is legal liability in cases of misdiagnosis or treatment errors involving AI. Who should be held responsible if AI makes a mistake—the software developer, the healthcare provider, or the medical institution? Additionally, there are regulatory and standardization issues that need to be addressed to ensure that the AI technology used is safe and effective.<sup>2,5</sup> When implementing AI in orthodontics, specific guidelines and standards are required to handle the ethical and legal issues. These laws should include safety and effectiveness criteria for AI technology, patient data protection, and methods for supervision and enforcement. Clear guidelines will assist in ensuring the safe and responsible use of AI technology, bringing trust to practitioners and patients.<sup>6</sup>

According to Kazimierczak et al.<sup>7</sup>, AI applications utilising convolutional neural networks (CNNs) in CBCT imaging have achieved diagnostic accuracy rates of up to 92.8%, with a sensitivity of 85.4% and a specificity of 96.7% for periapical lesion detection. In cephalometric analysis, AI achieved 88–92% accuracy, and in some cases, performed up to 80 times faster than manual tracing. These impressive results underscore AI's ability to analyse complex datasets quickly and accurately, making it a valuable tool to reduce

human error and enhance clinical efficiency in orthodontic care.<sup>7</sup> According to K ok et al. (2023), the study evaluated the performance of artificial intelligence in cephalometric landmark identification by comparing an AI-based software with two orthodontists. The statistical findings revealed that the intraclass correlation coefficients (ICC) for landmark identification between the AI system and orthodontist A ranged from 0.802 to 0.998. In contrast, those between the AI and orthodontist B ranged from 0.843 to 0.997, indicating excellent reliability across most landmarks. The lowest ICCs were observed in difficult-to-locate points such as Sella (0.802 with A) and Gonion (0.843 with B), but even these were within acceptable agreement levels. The mean differences between AI and human landmarking were mainly below 1 mm, aligning with the clinical threshold for acceptability in cephalometric analysis. These findings demonstrate that AI tools can provide consistent and reliable results that closely match manual tracing by experts, reinforcing their potential role in orthodontic diagnostics.

The integration of AI in orthodontics affects not only clinical practice but also orthodontic education. Dental students and professionals must be prepared to use this technology effectively and understand the accompanying legal and ethical implications. Educational curricula should include training in the use of AI, as well as discussions on relevant legal and ethical issues. This will help ensure that the next generation of orthodontic practitioners is ready to face the challenges and take advantage of the opportunities offered by AI.<sup>2</sup>

Several case studies have demonstrated the effective use of AI in orthodontics. For example, research has shown that AI can improve the accuracy of diagnosing orthodontic problems and

designing more effective treatment plans compared to traditional methods. However, these case studies also underscore the importance of addressing legal and ethical issues related to AI use, to ensure that this technology is used responsibly and beneficially for patients.<sup>8</sup> The future of AI in orthodontics is auspicious, with the potential to continuously improve the efficiency and effectiveness of orthodontic treatment. However, to realise the full potential of AI, it is essential to explore and address existing legal and ethical challenges continually. Collaboration between researchers, practitioners, regulators, and policymakers will be key to developing a framework that supports the safe and responsible use of AI.<sup>9</sup>

The integration of AI technology in orthodontics presents numerous potential benefits but also poses significant legal and ethical challenges that must be addressed. With the right approach, AI can become a highly valuable tool in orthodontic care, enhancing treatment outcomes and clinical efficiency. All stakeholders need to collaborate in developing regulations and standards that ensure the safe, effective, and ethical use of AI in the field of orthodontics. Through ongoing research and collaboration, we can maximise the benefits of AI while minimising its associated risks.<sup>10</sup>

## REVIEW

The use of AI in orthodontic diagnostics has shown significant advancements through the application of sophisticated technology and algorithms. AI technologies, such as machine learning and deep learning, enable the rapid and accurate processing of radiographic data and 3D models. These algorithms can detect malocclusions, analyze dental structures, and plan tooth movements with higher precision compared to conventional methods. For example, deep learning algorithms

can be optimized through training with large datasets from various orthodontic cases, thereby improving prediction accuracy over time. The implementation of this technology not only enhances diagnostic speed but also reduces human error, providing substantial added value in clinical orthodontic practice. However, challenges remain in terms of the initial data quality used to train these algorithms and the readiness of clinics to adopt this technology.<sup>11</sup>

AI technologies, such as machine learning and deep learning, have demonstrated significant capabilities in improving orthodontic diagnosis and treatment planning. AI can process radiographic data, 3D models, and patient medical histories to generate more accurate and faster diagnoses compared to conventional methods. This can reduce diagnostic errors and enhance treatment effectiveness.<sup>12</sup> The development of AI algorithms specifically for orthodontics enables automatic analysis of radiographic images, including the detection of malocclusions and planning of tooth movements. These algorithms can continuously learn and evolve based on new data, thereby improving their predictive capabilities over time. This advantage provides added value in clinical practice, reducing the time required for manual analysis.<sup>13</sup>

The use of AI in orthodontics not only enhances clinical accuracy but also offers economic benefits. By reducing the time needed for diagnosis and treatment planning, clinics can improve operational efficiency and serve more patients. Reducing medical errors can also lower costs associated with corrective treatments.<sup>14</sup> Implementing AI in orthodontics poses significant legal challenges. A primary issue is determining legal responsibility in cases of diagnostic or treatment

errors caused by AI. Questions about who is liable, the software developer, the healthcare provider, or the medical institution—must be answered to avoid litigation. AI requires access to large amounts of patient data to learn and make accurate predictions. This raises concerns about patient data privacy and security. Orthodontic clinics must ensure that patient data is protected from unauthorized access and misuse.<sup>15</sup>

According to K k et al. (2023), the study evaluated the performance of artificial intelligence in cephalometric landmark identification by comparing an AI-based software with two orthodontists. The statistical findings revealed that the intraclass correlation coefficients (ICC) for landmark identification between the AI system and orthodontist A ranged from 0.802 to 0.998. In contrast, those between the AI and orthodontist B ranged from 0.843 to 0.997, indicating excellent reliability across most landmarks. The lowest ICCs were observed in difficult-to-locate points, such as Sella (0.802 with A) and Gonion (0.843 with B), but even these were within acceptable agreement levels. The mean differences between AI and human landmarking were mainly below 1 mm, aligning with the clinical threshold for acceptability in cephalometric analysis. These findings demonstrate that AI tools can provide consistent and reliable results that closely match manual tracing by experts, reinforcing their potential role in orthodontic diagnostics.<sup>16</sup>

### **Legal Aspect**

The use of AI in orthodontics raises questions about liability and accountability in cases of diagnostic errors or treatment failures. Traditional legal frameworks are often ill-equipped to handle scenarios where an AI system makes a clinical

decision. Determining who is responsible—the AI developer, the healthcare provider, or the institution—can be a complex task. Legal scholars suggest the need for updated legislation that clearly defines the roles and responsibilities of all parties involved in AI-assisted clinical decisions.<sup>5</sup> AI systems in orthodontics require large datasets, often containing sensitive patient information, to function effectively. Ensuring the privacy and security of this data is paramount. Compliance with regulations such as the General Data Protection Regulation (GDPR) in the European Union and the Health Insurance Portability and Accountability Act (HIPAA) in the United States is essential. Breaches of data privacy not only have legal repercussions but can also damage patient trust and the reputation of the healthcare provider.<sup>12</sup> AI technologies used in orthodontics must undergo rigorous testing and obtain approval from relevant regulatory bodies, such as the U.S. Food and Drug Administration (FDA) or the European Medicines Agency (EMA). Establishing clear standards for the evaluation and approval of AI tools is necessary to ensure they are safe and effective for clinical use. This includes validation studies, clinical trials, and continuous monitoring post-implementation.<sup>5</sup>

In Indonesia, Law Number 17 of 2023 on Health offers a crucial legal foundation. This law recognises health technology as encompassing both physical tools and software, which means that AI systems used in dentistry are also covered. The law also emphasizes that any use or development of health technology must consider potential risks and be directed toward protecting public health.<sup>17</sup> The law broadly defines “health technology” to include both hardware and software (Article 334(2)), which explicitly encompasses AI as a

digital health tool. The implementation of artificial intelligence (AI) in dental care, especially in diagnostics and treatment planning, is indirectly governed by several key provisions within Indonesia’s Law No. 17 of 2023 on Health. Although AI is not explicitly mentioned, articles 27 and 29 emphasise that all healthcare services and technologies must uphold patient safety, clinical effectiveness, and quality of care. These principles are essential when integrating AI into clinical decision-making. Article 59 reinforces the protection of personal health data, stating that data collection and usage must respect confidentiality and require informed patient consent—an essential safeguard given AI’s dependence on large datasets. Articles 336 and 337 legitimize innovation and research in health technologies, encouraging the ethical development of tools like AI within regulatory frameworks. Article 344 mandates health technology assessment (HTA), requiring AI systems to undergo thorough evaluation to ensure their safety and efficacy before they are used clinically. Additionally, Articles 441 to 443 reinforce legal protections surrounding patient data, ensuring that AI applications comply with strict privacy and security standards. Together, these provisions provide a legal framework that, although not specific to AI, offers the ethical and procedural guidance necessary for the responsible and lawful integration of AI into dentistry.<sup>18</sup>

Patient data protection is another significant issue. AI systems require large volumes of data to train their models and make accurate predictions, often involving sensitive health information. Under regulations such as Indonesia’s Law No. 27 of 2022 on Personal Data Protection (UU PDP), such data is considered sensitive and must be handled with strict confidentiality. Dental practitioners

must ensure informed consent is obtained before data is collected or processed by AI systems. Furthermore, data must be stored securely and not shared without explicit patient authorisation. Violations may result not only in loss of trust but also in legal consequences, including administrative and criminal penalties.<sup>19</sup> The implementation of Artificial Intelligence (AI) in Indonesia's legal and law enforcement systems must be aligned with various national legal frameworks. The foundation begins with the 1945 Constitution of the Republic of Indonesia, particularly Article 28G(1), which guarantees every individual the right to feel secure and to be protected from threats to their privacy and safety. This article directly addresses concerns about the use of personal data in AI systems. Similarly, Article 28H(1) ensures the right to health and safety, implying that any technological advancement, including AI, must not compromise citizens' rights or well-being.<sup>20</sup>

Law No. 11 of 2008 on Electronic Information and Transactions (ITE Law), as amended by Law No. 19 of 2016, regulates digital communication, data processing, and electronic systems. These provisions are critical when considering AI applications that involve data collection, automated decision-making, or predictive analytics. If an AI system produces misinformation or violates privacy, the ITE Law provides a legal basis for accountability. Transparency in AI operations, especially within public institutions, is supported by Law No. 14 of 2008 on Public Information Disclosure. This law promotes open access to public information and requires that government technologies, including AI systems, be subject to public oversight. Clear protocols and auditability must therefore accompany the use of AI to ensure transparency and accountability. Intellectual property

considerations are addressed under Law No. 28 of 2014 on Copyrights, which updates the previous Law No. 19 of 2002. As AI systems generate various forms of outputs, including legal documents, data models, or even predictive tools, questions of authorship and ownership emerge. This law is essential in determining the rights of AI developers and regulating the commercialization of AI-generated content.<sup>20</sup>

### **Ethical Aspect**

The implementation of AI in orthodontics necessitates a re-evaluation of the informed consent process. Patients must be adequately informed about the role of AI in their diagnosis and treatment, including the potential benefits and risks. Transparent communication is essential to ensure that patients understand how their data will be used and the extent to which AI will influence clinical decisions. This helps build trust and ensure patient autonomy.<sup>21</sup> AI systems can inadvertently perpetuate existing biases present in the data used to train them. This can lead to disparities in treatment outcomes for different demographic groups. Ensuring fairness in AI applications requires careful selection and preprocessing of training data, as well as ongoing audits to detect and mitigate biases. Ethical AI deployment should strive for equitable treatment for all patients, regardless of their background.<sup>22</sup>

One primary ethical concern in the use of AI in orthodontics is the issue of equity and access. Not all clinics and patients have equal access to advanced technology, which can create disparities in the quality of care. Efforts must be made to ensure that the benefits of AI are enjoyed equitably by all segments of the population, without any form of discrimination. AI systems in orthodontics must

be transparent and explainable. Clinicians and patients should be able to understand how AI arrives at specific recommendations or decisions. This transparency is crucial for maintaining trust and for clinicians to validate and interpret AI-generated insights.<sup>23</sup> Explainable AI helps in ensuring that the technology is used as an aid rather than a replacement for professional judgment. Transparency in AI-generated decisions is an important aspect to consider. Patients and doctors need to understand how and why AI makes specific recommendations. This requires the development of transparent and explainable AI systems so that the decisions made can be trusted and accepted by all parties involved.<sup>24</sup>

Integrating AI into orthodontic practice requires that clinicians receive proper education and training on how to use these technologies effectively and ethically. This includes understanding the limitations of AI, interpreting AI-generated data, and effectively managing patient interactions that involve AI tools. Ongoing education ensures that clinicians remain competent in using advanced technologies and can uphold high standards of patient care. To maximize the benefits of AI, orthodontic professionals must be trained in using this technology. Dental education curricula should include training in AI and an understanding of its legal and ethical implications. This will help professionals in the field adopt new technologies responsibly and effectively. Developing clear regulations and standards for the use of AI in orthodontics is essential. These regulations should cover aspects such as safety, efficacy, and data privacy. With proper regulation, orthodontic clinics can ensure that AI use meets high ethical and legal standards. To address the challenges and maximize the benefits of AI in orthodontics, collaboration

among researchers, clinicians, technology developers, and policymakers is essential. This cooperation can help develop holistic and balanced solutions, combining technical expertise with a deep understanding of legal and ethical aspects.<sup>7</sup>

Respecting patient autonomy in orthodontic treatment means empowering individuals to make informed decisions about their care, particularly when artificial intelligence is involved in the process. In the context of orthodontics, patients must understand how AI technologies are utilised to analyse dental records, predict tooth movement, and develop treatment plans. This level of involvement requires clear and transparent communication from clinicians about the role of AI, including what data will be used, how it will be processed, and how it may shape clinical recommendations. Informed consent becomes not just a legal formality but an ethical necessity that ensures patients are actively involved in decisions that impact their oral health and appearance. Without this transparency, patients may feel uncertain or excluded from their treatment journey, which can undermine trust. Studies emphasise that respecting autonomy through informed consent is particularly important in orthodontics, where treatment outcomes often have long-term functional and aesthetic implications.<sup>25</sup> While respecting autonomy emphasizes the patient's right to choose, the principle of non-maleficence underscores the obligation of healthcare professionals to avoid harm. In orthodontics, this means ensuring that AI systems used in diagnosis and treatment planning do not lead to errors that could negatively affect the patient's oral health. For example, if an AI algorithm misinterprets cephalometric data or inaccurately predicts tooth movement, the resulting treatment plan could

cause discomfort, prolong treatment, or even worsen the malocclusion. Therefore, orthodontists must not rely solely on AI-generated recommendations without critical evaluation. They are ethically responsible for reviewing the accuracy, relevance, and applicability of AI outputs in each case. To truly uphold non-maleficence, AI tools must be rigorously tested, validated, and used as supportive aids rather than final decision-makers. Ethical literature stresses that while AI holds promise for improving precision, any potential for harm, such as incorrect analysis or inappropriate treatment suggestions, must be minimized through oversight and clinical judgment.<sup>26</sup>

The principle of beneficence emphasises the active promotion of good for the patient. In orthodontic care, this means utilising AI not only for convenience, but also to enhance the quality and outcomes of treatment. AI technologies can help orthodontists detect malocclusions earlier, design more precise treatment plans, and reduce the overall treatment time, ultimately improving the patient's experience and satisfaction. For instance, AI-assisted cephalometric analysis allows for more accurate predictions of tooth movement and skeletal growth. When used responsibly, AI becomes a tool that empowers clinicians to deliver better, more personalized care. Research emphasizes that when aligned with professional expertise, AI can significantly increase the effectiveness and efficiency of orthodontic interventions. The ethical principle of justice calls for fair and equal access to healthcare technologies, including AI. Not all patients come from the same socioeconomic background, and disparities in access to AI-based orthodontic services can widen the gap in oral health outcomes. Justice requires that the benefits of AI be made available to all, not only to

those who can afford high-end private care. Institutions and policymakers should work to ensure that AI applications in dentistry do not create a digital divide but instead promote inclusivity. This can be achieved by implementing AI tools in public dental services, subsidizing access where necessary, and ensuring transparent guidelines for their ethical use. Studies have warned that without such measures, AI may inadvertently perpetuate inequality, underscoring the urgent need for the equitable integration of technology into dental care systems.

## CONCLUSION

In conclusion, the integration of artificial intelligence in orthodontics holds substantial promise for enhancing diagnostic precision, streamlining treatment planning, and improving patient outcomes. However, to ensure its ethical and practical implementation, several strategic measures must be undertaken. AI competencies should be embedded within the dental education curriculum to equip future practitioners with the necessary skills and critical understanding of emerging technologies. Interprofessional collaboration involving dental professionals, legal experts, ethicists, and policymakers is essential to develop comprehensive regulations that address issues such as accountability, data governance, and informed consent. Additionally, ongoing auditing and evaluation of AI algorithms are needed to ensure they operate transparently, equitably, and remain clinically valid. These forward-looking approaches will support the responsible integration of AI in orthodontics, ensuring that technological advancements align with professional standards and patient safety.

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