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Research Article

Perception and Application of Dental Artificial Intelligence in Orthodontic Clinical Practice: A Cross-Sectional Survey of Orthodontists in Iraq

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Abstract

Background: The adoption of artificial intelligence is rapidly expanding and has significantly influenced orthodontic practice. ***Objective***: To investigate specialized orthodontists' perceptions and attitudes toward artificial intelligence in orthodontic practice. ***Methods***: An anonymous, web-based cross-sectional survey was conducted using Google Forms. An expert panel evaluated the survey instrument for content validity using Lawshe's method and for face validity by measuring inter-rater reliability. The survey comprised 25 closed-ended and one open-ended question organized into six sections. After its official release, the survey link was disseminated to all Iraqi Orthodontic Society members from January to March 2025. Descriptive statistics were performed to categorize the age groups of the participants. ***Results***: 101 valid surveys were collected and analyzed, highlighting a 63% response rate. The results revealed that although most respondents (61.4%) were aware of using AI-driven software programs, a significant percentage (40.6%) reported that they had never used such programs, underscoring a certain level of deficiency in applying AI in orthodontic practice. The awareness level was higher for AI applications in cephalometric analysis (60.0%) compared to other applications, such as orthognathic surgery and the biomechanics domain. ***Conclusions***: Generally, there was a good level of awareness and knowledge about AI's role in orthodontics, with strong readiness among the specialists to engage in AI-related training and integrate it into their clinical routines. The study supports further education, training, evidence-based validation, and designing more AI-powered tools addressing different domains of orthodontics, particularly biomechanics, which are essential to bridge the trust gap.

Keywords: Artificial intelligence, Attitudes of health personnel, Clinical practice, Knowledge, Orthodontics, Perceptions.

أدراك وتطبيق الذكاء الأصطناعي في طب الأسنان في الممارسة السريرية لتقويم الأسنان: دراسة مقطعية لأخصائيي تقويم الأسنان في العراق

الخلاصة

الخلفية : يشهد استخدام الذكاء الاصطناعي توسعًا سريعًا أثر بشكل كبير على ممارسة تقويم الأسنان. **الهدف**: تحري و دراسة تصورات و مواقف أخصائيي تقويم الأسنان تجاه الذكاء الاصطناعي في ممارسة تقويم الأسنان. **الطرائق**تم إجراء مسح مقطعي مجهول الهوية عبر الإنترنت باستخدام نماذج جوجل. قام فريق من الخبراء الاختصاص بتقييم صلاحية المحتوى بطريقة لوشي و تقييم الصلاحية الظاهرية من خلال قياس درجة التوافق بين المقيمين. تضمّن الأستبيان 25 سؤالًا مغلقًا وسؤالًا واحدًا مفتوحًا، موزعة على ستة أقسام. بعد الاصدار الرسمي تم توزيع رابط الاستبيان على جميع أعضاء جمعية تقويم الأسنان العراقية خلال الفترة من كانون الثاني الى اذار 2025. **النتائج**: تم جمع و تحليل 101 استبانا صالحا و مصدقا، و كانت نسبة الاستجابة 63%. اظهرت النتائج أنه على الرغم من أن 61.4% من المشاركين كانوا على دراية باستخدام برامج مدعومة بالذكاء الاصطناعي، فإن 40.6% منهم أفادوا بعدم استخدامها لهذه البرامج من قبل، مما يبرز وجود قصور في تطبيق الذكاء الاصطناعي في مجال تقويم الأسنان. كان مستوى الوعي أعلى بالنسبة لتطبيقات الذكاء الاصطناعي في التحليل السيفالومتري (60.0%) مقارنة بالتطبيقات الأخرى، مثل جراحة الفكين و مجال البايوميكانيك. **الاستنتاج**: هناك مستوى جيد من الوعي والمعرفة بدور الذكاء الاصطناعي في تقويم الأسنان، مع استعداد قوي لدى الأخصائيين للمشاركة في التدريبات المتعلقة به واستخدامه في روتينهم السريري. تدعم الدراسة ضرورة تعزيز التعليم و التدريب و اجراء بحوث اكثر لتقديم ادلة مستندة و تصميم المزيد من الادوات المدعومة بالذكاء الاصطناعي التي تركز على مجالات تقويم الاسنان المختلفة و خاصة البايوميكانيك و هي امور اساسية لسد فجوة الثقة.

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INTRODUCTION

Artificial intelligence is an innovation that refers to the development of robots that can imitate human thinking and operate autonomously with minimal human intervention [1,2]. Many branches of dentistry have benefited from AI advancements, such as radiology, periodontics, oral pathology, oral surgery, endodontics, prosthodontics, and orthodontics [3–7]. AI has revolutionized orthodontics. It has been employed to predict orthodontic treatment needs and treatment planning, digitize and trace cephalometric landmarks with 90% accuracy, and assess growth by determining the degree of maturation of cervical vertebrae.

Moreover, AI has been implemented for facial analysis [8]. Orthodontic research has investigated the application of AI in areas such as extraction decision-making, airway analysis, evaluating the necessity of orthognathic surgery, and estimating facial aesthetics after orthognathic surgery to enhance accuracy and avoid bias from less experienced professionals. Most AI models in this field rely primarily on ANNs or CNNs [9–11]. Tele-orthodontics represents an innovation in the remote monitoring of orthodontic treatment in patients with clear aligners [12]. As a high-performance assistant tool, are AI-based systems likely to replace orthodontists in specific tasks? With the rapid progression of AI technologies, the world evolves every day. Numerous studies [11,13–20] have assessed the perspectives of dental experts and students regarding artificial intelligence technology. However, studies focusing on AI applications in orthodontics within the "Middle East and North Africa region" are limited, resulting in insufficient comprehensive data on this subject. To the best of our information, this research constitutes the first study conducted in Iraq exploring the perception, attitudes, and application of dental artificial intelligence among orthodontic specialists. Therefore, the present research aims to inspect the related perceptions and attitudes of Iraqi orthodontists (academicians and clinicians with a higher education degree) toward using artificial intelligence in their clinical practice and highlight their opinions toward AI-based applications and related influencing factors. Additionally, it investigates their predictions regarding the future evolution of AI in orthodontic practice in Iraq, aiming to offer recommendations for improvements to existing AI applications and prospective avenues for interdisciplinary AI research in orthodontics.

METHODS

Study design and sampling approach

A cross-sectional study was conducted among orthodontists in Iraq (academicians and clinicians with higher education qualifications) affiliated with the accredited Iraqi Orthodontic Society (IOS). The surveylength.com.lnk tool was used to determine the survey's completion time. Based on respondents' percentages by questionnaire path, age, type, and number of questions, the tool estimated a 5-minute completion time. The response rate was determined by dividing the number of survey responders by the number of contacted and addressed IOS members (currently, the IOS has 160 registered Iraqi orthodontists in its records).

Survey development, design, and validation

Step No. 1: Item development by authors. The authors created a pool of questions after a comprehensive evaluation of several previous studies [8,11,15,17,21,22]. Step No. 2: Item development in consultation with six orthodontic experts. Six qualified orthodontic experts were invited to share their thoughts on the key questions that should be included in the survey to address the most relevant aspects and highlight major concerns regarding dental AI in orthodontic practice in Iraq. All these experts were academicians with advanced academic qualifications in orthodontics and working in four different and well-recognized universities in Iraq, with various levels of clinical experience (more than ten years), and from diverse geographical areas (Table 1).

Table 1: Specialization and professional background of experts for survey development and content validation

Expert Code	Expertise	Years of academic and clinical experience in orthodontics
E 1	Senior specialist at Orthodontic Department, College of Dentistry, Baghdad University.	18 years
E 2	Senior specialist at Orthodontic Department, College of Dentistry, Mosul University.	20 years
E 3	Senior specialist at Orthodontic Department, College of Dentistry, Sulaymaniyah University.	17 years
E 4	Senior specialist at Orthodontic Department, College of Dentistry, Sulaymaniyah University.	18 years
E 5	Senior specialist at Orthodontic Department, College of Dentistry, Hawler Medical University.	17 years
E 6	Senior specialist at Orthodontic Department, College of Dentistry, Hawler Medical University.	12 years

The expert panel was provided with detailed information about the survey's aim, target group, development process, and content validation procedures, ensuring they were well-informed of all the necessary details to develop carefully structured and valid survey items in line with Waltz *et al*. [23] and Davis [24]. The initial draft of the survey included 29 closed-ended questions. Step No. 3: Survey validation. An expert panel for content and face validation evaluated the survey instrument. Lynn characterized content validity as a thorough evaluation, staging two parts, "construction and evaluation steps," essential to nearly every assessment in the survey instrument [25].

Validation types and procedures

The survey items were validated for their contents in two phases using the content validity ratio (CVR) and content validity index (CVI) according to Lawshe's method [26]. For this research study, the same six

orthodontic experts (Table 1) were invited again to participate in the content validity procedure. These experts were purposefully selected following the recommendations of Grant and Kinney [27]. The overall survey demonstrated a high level of content validity, with a Content Validity Index (CVI) of 0.96, which indicates perfect agreement and roughly excellent content validity as recommended by Waltz [28]. Face validation was performed to ensure the survey items are feasible, readable, well-formatted, stylistically appropriate, and evident in language [29]. The face validity of this survey instrument was assessed by measuring inter-rater reliability using the percent agreement and Cohen's kappa statistics. Two orthodontic experts were appointed and invited to assess the face validity (Table 2).

Table 2: Expert panel for face validation

Expert code	Qualification	Expertise	Years of academic and clinical experience in orthodontics
E 1	PhD in Orthodontics	Senior specialist at Orthodontic Department, College of Dentistry, Hawler Medical University.	17 years
E 2	MSc in Orthodontics	Senior specialist at Orthodontic Department, College of Dentistry, Hawler Medical University.	17 years

The survey items achieved an agreement rate of 85% and Cohen's kappa of 0.72, reflecting good inter-rater reliability consistent with Altman's interpretation of 0.61 and above [30]. A panel of five orthodontists, responsible for the postgraduate orthodontic department, reviewed the final draft of the survey before its official release. The final version of the validated survey consisted of 25 closed-ended questions and one open-ended question distributed across six sections. The first section involved six questions: five closed-ended single-choice items and one open-ended question (Q2) about the demographic information and professional background. The second section, with six items, two multiple-choice items (Q1 and Q2) and four single-choice items (Q3-Q6), aimed to evaluate participants' fundamental knowledge and awareness of AI use and application in orthodontics. The third section, with three single-choice items, focused on specialists' perceptions of using AI in their clinical orthodontic practice. Section four explored participants' attitudes toward using and integrating AI in orthodontic practice. It included three items: one Likert-scale item (Q1), one multiple-choice item (Q2), and one single-choice item (Q3). The fifth section, with three items, two Likert-scale items (Q1 and Q3), and one multiple-choice item (Q2), evaluated the impact of dental AI on clinical decision-making, treatment quality, and accuracy in orthodontics. The last section involved one multiple-choice item (Q1), and the other four are single-choice items, encompassing respondents' views on the current challenges and barriers to adopting AI in orthodontics and exploring the expectations for AI's future evolution in Iraq.

Data collection

A web-based anonymous survey was developed and circulated via the Google Forms platform. The scientific research ethics committee at the College of Dentistry, Hawler Medical University (Reference No: HMUD,2425158), on 26/10/2024, approved this questionnaire. Responses were limited to only once per participant to ensure the research's integrity and neutrality. The questionnaire was structured logically to ensure its relevance and accuracy in obtaining responses, as demonstrated in Q3 of Section 2. The orthodontists were asked whether they were aware of using AI-powered software programs for diagnosis and treatment planning in orthodontic practice. Based on their response, if they answered 'Yes,' they would be transferred to Q4, Q5, and Q6. If they answered 'No,' they wouldn't be guided to the subsequent three questions. Therefore, depending on the selection made by participants, the next set of questions was either presented or omitted. An invitation letter and the survey link were sent to the IOS members' orthodontic forum to invite all active members to participate. Three weeks later, the link was resent as a reminder for non-respondents. The first section of the Google form included a clear description of the purpose of the study, the target survey group, and appreciation for participating in this research study. Furthermore, participants were notified explicitly that completing the survey is entirely voluntary and is regarded as granting informed consent for participation. Participants weren't required to provide a Gmail address or phone number, and no tracking tools were used to ensure respondents' confidentiality. This questionnaire was circulated from January to March 2025.

Ethical considerations

The scientific research ethics committee at the College of Dentistry, Hawler Medical University (Reference No: HMUD,2425158 on 26/10/2024), approved the questionnaire.

Statistical analysis

Content validity was evaluated based on the CVR of an item and CVI for the overall survey instrument using an Excel workbook (Excel, Microsoft Office LTSC Professional Plus 2021, Redmond, Washington, USA) to compile and save feedback from both phases of content validation. Face validation was analyzed by computing percent agreement in the same Excel software program and Cohen's kappa statistics using DATAtab software in a paid subscription version, "DATAtab Team (2025). DATAtab: Online Statistics

Calculator. DATAtab, e.U. Graz, Austria. URL https://datatab.net." Descriptive statistics were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA) software.

RESULTS

101 active members out of 160 registered orthodontists in the accredited IOS, with higher education credentials in orthodontics, completed the online survey, reflecting a 63% response rate. Results illustrated that 101 participants ranged in age from 28 to 67 years, with a mean age of 41.3±7.9. Over one-third were between 38 and 47 years old (46.5%). (53.5%) were females, and (46.5%) were males. The majority of respondents (64.4%) had MSc credentials in orthodontics. A large proportion of participating specialists had over ten years of clinical expertise in the orthodontic field. Orthodontic specialists from diverse institutions across Iraq were included in the study. Furthermore, the participants in this survey were primarily affiliated with the Ministry of Higher Education and Scientific Research (61.4%) and mainly based in the northern region of Iraq (48.5%), followed by the central region of Iraq (39.6%). Table 3 represents the demographic characteristics of the study participants.

Table 3: Demographic data and professional background of the survey participants (n=101)

Characteristics	n(%)
Gender	
Female	54(53.5)
Male	47(46.5)
Age groups (Year)	
28-37	36(35.3)
38-47	47(46.5)
48-57	15(14.9)
58-67	3(3.0)
Highest academic qualification	
MSc in orthodontics	65(64.4)
PhD in orthodontics	36(35.6)
Years of clinical experience in orthodontics	
<5 Years	22(21.8)
5-10 Years	28(27.7)
>10 Years	51(50.5)
Institutional information	
Ministry of Health	37(36.6)
Ministry of Higher Education and Scientific Research	62(61.4)
Others	2(2)
Region of residence	
Northern region of Iraq	49(48.5)
Central region of Iraq	40(39.6)
Southern region of Iraq	6(5.9)
Eastern region of Iraq	3(3)
Western region of Iraq	3(3)

As illustrated in Figure 1, professional education (45.5%) and social media (41.6%) were the main sources for learning about AI software programs specifically designed for orthodontics, followed by web browsing (33.7%), scientific journals and books (23.8%), and family and colleagues (14.9%), while 11.9% of participants stated that they had never obtained AI-related information from any source. Among the respondents, 40.6% reported never using any AI orthodontic software. WebCeph was the most commonly used AI software program, with 35.6% of participants indicating its use. The least widely used software was NEMOFAB, reported by only 2.0% of participants (Figure 2).

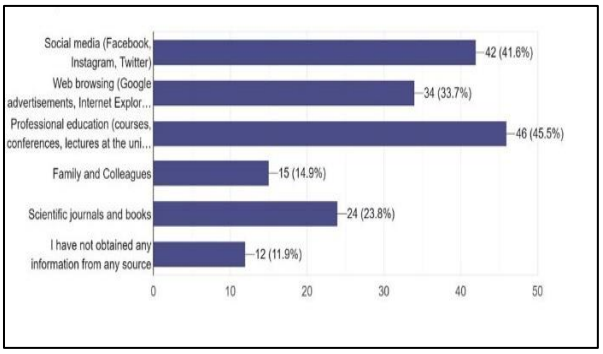

Figure 1: AI Knowledge and awareness reference points for the participants.

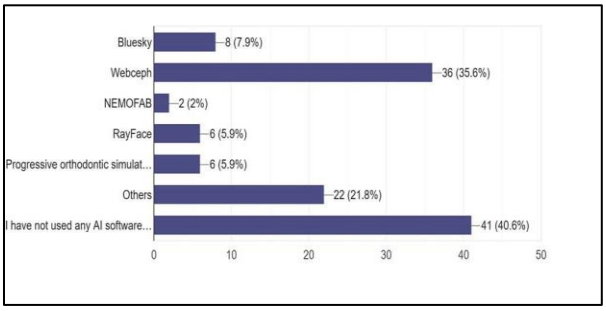

Figure 2: Distribution of AI orthodontic software usage among respondents.

Out of 101 participants, 61.4% reported awareness of using AI-driven software programs for orthodontic diagnosis and treatment planning, while 38.6% indicated they were unaware of such tools. Table 4 represents orthodontists' knowledge and awareness of AI regarding Q4-Q6 in this section. Among 61.4% of the respondents who stated their awareness of AI-based software programs for diagnosis and treatment planning, 98.4% were highly aware of the use of AI in digitization and lateral cephalometric analysis, followed by 67.7% of them who were knowledgeable about AI's role in the preparation and planning for orthognathic surgery and in correcting facial aesthetics. In comparison, only 41.9% were familiar with using AI-based tools to predict canine impaction, determine the geometry of orthodontic springs to apply force for teeth alignment, and software for selecting the appropriate headgear. A total of 101 respondents (52.5%) confirmed that AI plays a role in saving time for diagnosis and treatment planning in orthodontics. However, 46.5% expressed a notable level of uncertainty, while only 1.0% rejected the role of AI in this respect. A significant portion of respondents (79.2%) reported they would trust their own clinical judgments if they had faced differences between AI decision-making and their decisions.

Table 4: Orthodontists' knowledge and awareness of AI regarding responses to (Q4-Q6) in section No.2. (n=62)

No.	Characteristics	Yes	No
Q4	Awareness of AI use in digitization and lateral cephalometric analysis	61(98.4)	1(1.6)
Q5	Awareness of AI's role in the preparation and planning for orthognathic surgery or in the correction of facial aesthetics.	42(67.7)	20(32.3)
Q6	Familiarity with using AI-assisted tools, such as for the prediction of canine impaction, determining the geometry of orthodontic springs to apply force for teeth alignment, and software for selecting the appropriate headgear	26(41.9)	36(58.1)

Values were expressed as frequency and percentage.

In contrast, 17.8% expressed uncertainty in this respect, while only 3.0% indicated trust in the AI's decision. Concerning the effectiveness of AI-powered software for diagnosis and treatment planning compared to experienced professional orthodontists. Interestingly, 49.5% refused the idea that AI performance surpasses that of skilled specialists, 47.5% indicated uncertainty, and only 3.0% perceived that AI-powered software might exceed the diagnostic and treatment planning abilities of the specialist orthodontists. Concerning the use of AI-powered tools in orthodontic practice, 33.7% of the surveyed orthodontic specialists reported frequent usage. In comparison, 32.7% indicated rare usage, and 30.7% reported no usage. Only 3.0% of participants mentioned consistent and regular usage of AI-driven tools in their orthodontic clinical practice. The survey findings offer profound insights into orthodontists' perspectives on AI integration in orthodontics. Over half of the respondents **(**61.4%**)** supported AI applications for clear aligner treatment**.** Similarly, CBCT and lateral cephalometric analysis with simulation (57.4%) and diagnosis (55.4%) were among the most promising areas for AI implementation in orthodontics. Additionally, 50.5% of respondents expressed interest in AI applications for patient education and communication. In contrast, biomechanical determination of orthodontic treatment (12.9%) was reported as the least preferred area for AI implementation in orthodontics (Figure 3).

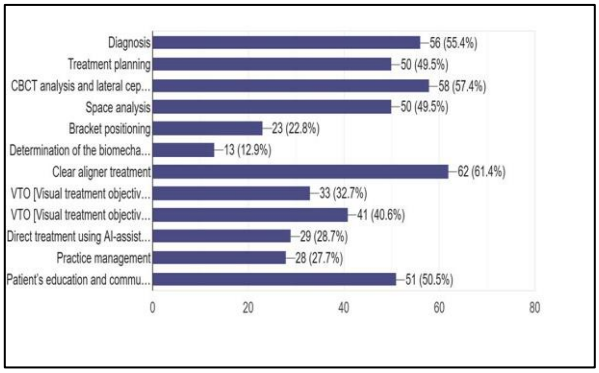

Figure 3: Attitudes toward AI implementation across different orthodontic domains.

Notably, the vast majority of surveyed Iraqi orthodontists (94.1%) expressed a strong desire to undergo formal AI training and incorporate AI-powered tools into their clinical practice. Conversely, only 5.9% showed no interest in this subject. The results revealed varying degrees to which AI influences clinical decision-making in orthodontic diagnosis and treatment planning. Of the 101 respondents, 50.5% observed that AI somewhat improved their clinical decision-making capabilities, while 16.8% indicated significant improvement. In contrast, 32.7% reported no impact. Interestingly, none of the participants in the surveyed group reported adverse impact, suggesting a generally favorable perception of AI among Iraqi orthodontists. Additionally, the survey examined the influence of dental AI on three fundamental aspects of orthodontic practice: efficiency, accuracy in orthodontic diagnosis and treatment planning, and patient experience, as illustrated in Figure 4.

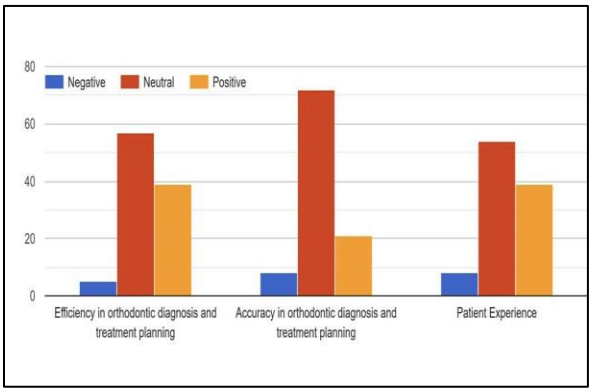

Figure 4: Impact of AI on efficiency and accuracy in orthodontic diagnosis and treatment planning, as well as patient experience.

In the context of efficiency, 39.0% of respondents rated a positive impact, 57.0% rated neutral, and 5.0% indicated a negative impact. Regarding accuracy, 21.0% of participants observed a positive impact, approximately 72.0% perceived a neutral impact, and 8.0% expressed a negative impact. Finally, concerning the impact of AI on patients' experiences, (39.0%) mentioned a positive influence, (54.0%) rated it neutral, and (8.0%) reported a negative effect. These findings highlighted a neutral perception of dental AI's impact on these key areas of orthodontics. Furthermore, the minimal rating of negative impact supports a positive impression of AI in orthodontic practice in Iraq. Regarding AI's proficiency in improving treatment quality and accuracy in orthodontics, just over half of the surveyed specialists (53.5%) reported agreement, while 8.9% strongly agreed. However, 2.0% expressed disagreement, and 7.9% strongly disagreed. Meanwhile, 27.7% maintained a neutral perspective. The primary challenge identified in adopting AI in orthodontic

practice was the high cost of creation and design, as reported by 68.3% of respondents, followed by a lack of training (61.4%) and concerns regarding accuracy and effectiveness (49.5%). Notably, only 16.8% of respondents had concerns about data privacy (Figure 5). Survey results revealed that 59.4% of participants strongly rejected the idea that AI could potentially take over the role of orthodontists in clinical settings, with only 6.9% believing it could and 33.7% remaining uncertain, indicating a "may be" response.

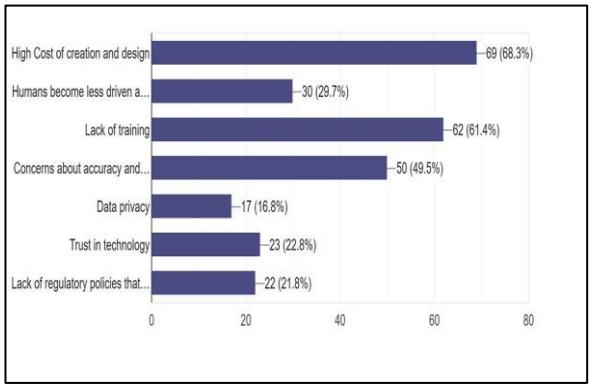

Figure 5: Distribution of challenges for integrating AI in orthodontic practice.

45.5% of orthodontists expressed confidence in using AI-driven programs for diagnosis and treatment planning of complex cases, while 48.5% expressed uncertainty, and only 5.9% rejected the concept entirely. Iraqi orthodontic specialists predict a significant AI role in future orthodontics, with a majority (60.4%) expecting a positive outlook, while 37.6% reported uncertainty, and only 2.0% expected no significant role. The surveyed orthodontists overwhelmingly supported the inclusion of AI-related education and training in undergraduate and postgraduate programs, with 95.0% in favor and only 5.0% expressing disapproval.

DISCUSSION

In today's AI-driven world, orthodontics is embracing a revolutionary shift, surpassing the confines of traditional clinical approaches, which makes it essential for orthodontists to stay updated with AI technology and advancements. This study was designed to perform a valid survey to explore the extent to which Iraqi orthodontists are implementing AI-driven tools in orthodontic diagnosis, treatment planning, patient management, and monitoring, with other possible AI applications, and to support orthodontic professionals with a valuable guide to assist in advancing future interdisciplinary research and innovation. No up-to-date studies have been published regarding assessing perceptions, attitudes, and application of dental artificial intelligence that exclusively targeted orthodontic specialists. The latest published surveys in orthodontic communities in other regions worldwide addressed the knowledge, attitudes, perceptions, and usage of AI applications by orthodontists and orthodontic residents [11,22,31], and a recent survey by Hanenkrath *et al*. [8] assessed the use of AI in postgraduate orthodontic programs in North America. This survey's lowest percentage of participants came from the southern, eastern, and western regions of Iraq. This is attributed to the shortage of orthodontic specialists in these areas, unlike in the northern and central parts of the country. The primary source of AI knowledge and awareness was professional education. This finding is in accordance with those of other surveys [11,31], but in contrast to a study conducted by Mengi *et al*. [22], where the major sources were web browsing and social media. Although more than half of orthodontists (61.4%) expressed positive awareness of using AI-powered software programs for diagnosis and treatment planning, A significant 40.6% of respondents reported that they had never used any AI-driven orthodontic software, underscoring a notable gap in AI adoption in clinical orthodontic practice. In addition, only 3% of participants consistently incorporate AI into their practice, while 33.7% use it frequently. Moreover, more than half of the participants described the impact of AI on the efficiency and accuracy of orthodontic diagnosis, treatment planning, and patient experience as 'neutral.' Furthermore, only half of the participants perceived a slight improvement in their clinical decision-making, with a small minority reporting a significant improvement. This might result from multiple challenges, including financial constraints, unfamiliarity with technology, doubts about its efficiency and accuracy, and a deficiency of well-organized workshops and educational webinars within this field in the country. Our results are reasonably close to those reported in a survey by Gupta *et al*. [31]. There was a general expectation that AI would play a significant role and have a fantastic future in orthodontic practice. Most participants were aware of AI's use in orthodontic treatment planning. Furthermore, lateral cephalometric analysis was among the most well-accepted AI applications, with strong positive attitudes toward its integration into clinical practice and notable practitioner awareness. This can be explained by the current availability of numerous AI-driven platforms for cephalometric digitization and analysis. Some are freely accessible, while others are offered at reasonable prices, which has enhanced their widespread adoption and utilization. In addition to the extensive volume of evidence-based studies supporting the reliability of many AI-driven software products in cephalometric digitization and analysis, this has played a key role in fostering user trust in these applications, such as the studies conducted by Surendran *et al*. [32], Katyal and Balakrishnan [33], and Chuchra *et al*. [34]. 41% of this study's participants were aware of AI's role in preparing and planning orthognathic surgery. These results were not in agreement with the study conducted by Gupta *et al*. [31], where 74% of faculty members agreed with AI

use in 3D planning for orthognathic surgery, and the survey by Mengi *et al*. [22], in which 86% of participants agreed that AI could help in clinical judgment for orthognathic surgery. The low level of awareness of AI's role in orthognathic surgery suggests the need for further training, exposure, and evidence-based validation to motivate the specialists and enhance AI practice in these domains. Regarding biomechanics, orthodontists exhibited the least awareness, familiarity, and support for AI integration. This contrasts their strong positive attitudes toward AI adoption in clear aligner treatment. This could be attributed to the perception that biomechanics is a crucial field in orthodontics that relies heavily on orthodontists' professional judgment and skills. Relatively limited availability of specialized programs in biomechanics, coupled with a lack of marketing initiatives, webinars, or workshops aimed at promoting AI tools in this domain, especially compared to other areas, such as AI adoption in clear aligners, where such resources are more prevalent. In addition to the numerous workshops, webinars, and lectures held almost continuously worldwide and the robust marketing strategies for different types of aligners in particular, the widely recognized Invisalign® technique [35]. Given the rapid advancements in research and development within this field, we can anticipate the emergence of more all-encompassing AI tools that address every aspect of orthodontics. Our survey study indicated that more than three-quarters of specialists chose to rely on their clinical decisions whenever conflict arose with AI's decisions. This aligns with the findings from the Mengi *et al*. questionnaire [22]. This concern is understandable due to AI's limited ability to adapt to the complexities of clinical decision-making. Adequate healthcare depends on a strong physician-patient relationship, which AI implementation challenges, as it may not recognize the crucial psychological, mental, and cultural factors essential to an individual's health and comfort [36]. This questionnaire's findings diverge from those that Gupta *et al*. [31] reported in several key areas. Half of the participants in this study have over ten years of clinical experience in orthodontics, unlike Gupta et al.'s (16.0%), as this questionnaire focused on specialists. Furthermore, the current study indicated that only 3.0% believed that the performance of AI-driven tools might exceed that of a professional orthodontist, in contrast to 44.67% of Gupta et al.'s findings. The majority of participants in this study believed orthodontists could never be replaced by AI, with only 6.9% in agreement. Meanwhile, more than one-third expressed confidence in relying on AI as a secondary tool for judgment in challenging cases. This can be interpreted as AI generally being perceived as a complementary tool in orthodontic decision-making. In a recent study conducted by Rokaya *et al*. [37], it was illustrated that AI showed several inaccuracies in evaluation and assessment. Therefore, a qualified clinician must perform the final inspection to prevent these kinds of mistakes. An impressive percentage of participants in this survey (95.0%) strongly recommended AI training in the undergraduate and postgraduate curricula. Concerning postgraduate training, a lower rate was observed in the findings of the Gupta *et al*. survey [31]. In a most recent study by Hanenkrath *et al*. [8], it was reported that only half of the North American postgraduate orthodontic programs plan to implement AI, and 87.8% indicated they had not incorporated any seminar/training into their programs to train the orthodontic residents.

Key strengths of the study

This research stands as the first and uniquely original study of its kind to be performed in Iraq for the validation types and procedures, subsequently considering its defined scope to investigate specialist orthodontists' knowledge and attitudes toward applying dental AI-driven tools into their clinical practice. The survey was validated by a panel of experts who were highly experienced and well-qualified to assess the field under study. The standards for selecting the expert panel, the detailed information they received on the questionnaire design, content validation procedures, and the structure of the invitation letter were all aligned with the guidelines authored by Grant and Davis [38]. Despite the ease of calculating Lawshe's CVR, its interpretation can be complex, as its scores lie between -1.0 and +1.0; a CVR of zero indicates that half of the experts considered an item relevant, and such items are often excluded, as zero falls below the acceptable threshold [39]. The study exclusively targeted orthodontic specialists with advanced training and a deeper understanding of orthodontic principles. Since specialists are at the forefront of integrating new technologies through research, training, or direct patient care, making them the most qualified group sample strengthens the research validity by capturing experts' perspectives, helping to predict AI's potential influence on clinical orthodontic practice. Furthermore, the survey received a response rate of 63%, exceeding the 44% threshold recommended for online surveys in the education field in a meta-analysis by Wu *et al*. [40]. This active participation rate underscores the importance of the research topic and further reinforces the study's clinical and academic relevance.

Limitations of the study

Given the scope of this research, it is necessary to address sample size-related bias since not all orthodontic specialists in Iraq are registered with the Iraqi Orthodontic Society. Moreover, the sample may not fully represent the broader population, considering that the principle under investigation is likely to be more familiar and understood by younger individuals than by older individuals. It is also critical to recognize the voluntary self-preference bias. This can be explained by

two key factors: first, election bias is inevitable, as respondents likely had a preexisting interest in AI; second, the potential for self-reported response bias may limit the generalization of our results, especially for those who have not used AI in orthodontics and those with inadequate knowledge or negative experiences with AI technology. Furthermore, the conditions and settings in which the survey was administered could have impacted the responses, leading to bias.

Conclusion

Overall, there was a good level of awareness and understanding regarding AI's role in orthodontic practice. Specialists showed a robust willingness to participate in AI-related training and integrate it into their professional routines, with broad agreement on the need to include it in undergraduate and postgraduate programs. The study advocates for ongoing education, training, evidence-based validation, and the development of additional AI-powered tools that address various aspects of orthodontics, especially biomechanics. Orthodontists should be encouraged to embrace AI as a supportive resource while prioritizing patients' well-being in clinical decision-making.

Recommendations

Based on the conclusions of this study, it is suggested to broaden educational, training, and awareness initiatives to help professionals understand the benefits and practical applications of AI-powered programs in orthodontics. This should also raise awareness about AI integration within orthodontic biomechanics, intensify research efforts, and develop advanced AI-based models specific to this field. Encouraging collaboration between orthodontists and AI programmers to address challenges and integrate professional human skills into AI tasks is essential. Conducting longitudinal studies would be highly beneficial for exploring the impact of integrating AI into undergraduate and postgraduate orthodontic curricula and evaluating the effectiveness of various educational and training methods. To improve understanding of how AI technologies influence orthodontic clinical practice and provide evidence-based foundations supporting AI's validity, further research should focus on examining the long-term effects of AI applications in orthodontics, including patient education and monitoring, accuracy of diagnosis, clinical decision-making, and care effectiveness.

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Conflict of interests

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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