



International Journal of Scientific Research in Dental and Medical Sciences

www.ijstdms.com



Diagnostic Accuracy of Artificial Intelligence in Bone Density in Implant Surgery: A Systematic Review and Meta-analysis

Zahra Mardani ^a, Ali Salehi ^b, Fatemeh Jabbarpor ^{c, *}, Bahare Azizi ^d, Nazanin M-Abdi ^e

^a Orthodontics Unit, Department of Plastic Surgery, Hospital and Burn Research Center, Iran University of Medical Sciences, Tehran, Iran

^b Department of Oral and Maxillofacial Radiology, Isf. C, Islamic Azad University, Isfahan, Iran

^c Department of Periodontics, Isf. C, Islamic Azad University, Isfahan, Iran

^d Independent Researcher, Sanandaj, Iran

^e Department of Pediatric, T.C., Islamic Azad University, Tehran, Iran

ARTICLE INFO

Article history:

Received 05 February 2025

Received in revised form 22 March 2025

Accepted 02 April 2025

Available online 11 April 2025

Keywords:

Artificial Intelligence

Bone Density

Diagnosis

ABSTRACT

Background and aim: Artificial intelligence has garnered significant attention recently, and its application in medicine and dentistry has been proposed. However, few studies have been done in the field of dental implants. Investigating the factors affecting its accuracy is also very important. Therefore, the present study was conducted to investigate the diagnostic accuracy of artificial intelligence in bone density in implant surgery.

Material and methods: The relevant published literature was gathered through a systematic search of four electronic databases: Web of Science, Scopus, MEDLINE/PubMed, and Cochrane. The developed PICO question served as the basis for the search terms. Only articles published in English within the previous five years (January 2019 and February 2025) were included in the search. The accuracy of AI was used as an effect size in a fixed-effects model and inverse-variance methods, with 95% confidence intervals (CI). All data analysis was performed using Stata.v18 software (latest version; year 2025).

Results: Artificial intelligence-guided implant surgery was 87% accurate (ES 0.87, 95% CI: -0.01, 1.75). According to meta-regression, a higher bone density increased the risk of angular and implant apex deviations.

Conclusions: According to the present meta-analysis, the accuracy of the implant pattern designed with artificial intelligence is high, and bone density is higher than the reasons that can lead to implant deviation.

1. Introduction

Digital technology could enable guided implant surgery, thereby increasing implant insertion accuracy and reducing potential problems during the procedure. This would make surgery easier for the patient to comprehend and accept.^[1] Based on previous studies, clinicians and patients have recently preferred guided implant surgery over conventional methods. The reason for this is higher accuracy and reduced operation time.^[2-4] Guided implant surgery necessitates modifying conventional surgical techniques. Most dental implants are still placed free-hand because of the additional preoperative analysis required by the template design software program, as well as the time clinicians must invest in learning its related functions. Artificial intelligence (AI) has been developed to mimic human reasoning and carry out tasks such as problem-solving, object recognition, and decision-making, which typically require human intelligence.^[5, 6] According to in vitro research, Self-learning AI systems in dentistry can accurately identify caries, fractures, and root canal orifices with remarkable results.^[7-9] AI technology can automatically

recognize the 3D contours of implant areas and create a database of situations with different edentulous sites.^[10] An implant template system that utilizes artificial intelligence (AI) can alleviate clinicians of the burden of gathering data and evaluating numerous medical images.^[6] Furthermore, even with guided implant surgery, a nonuniform density distribution during the osteotomy preparation procedures may increase the risk of drill shifting.^[11]

The accuracy and aesthetic results of maxillary anterior teeth implant surgery using flapless guided technology were assessed in a study. According to their findings, 19% of the implants were lingually positioned, and 70% were labially positioned, resulting in a buccolingual direction deviation. This finding suggested that bone density might influence the accuracy of guided surgery.^[12] Others have noted that the implant position (maxillary or mandibular) does not significantly affect the accuracy of guided implants. These studies' research objectives, dentition defects, and guided surgery protocols may result in differing conclusions. It is essential to remove the

* Corresponding author. Fatemeh Jabbarpor

E-mail address: f.jabbarpour@iau.ir

Department of Periodontics, Isf. C, Islamic Azad University, Isfahan, Iran

<https://doi.org/10.30485/IJSDMS.2025.510789.1645>



inherent error factors of surgical templates and investigate how density affects errors in guided implant surgery in clinical applications.^[13] The purpose of the present study was to evaluate the diagnostic accuracy of artificial intelligence in bone density in implant surgery.

2. Material and methods

In the current study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guide was used to systematize and compile the research.^[14]

Inclusion and exclusion criteria

Table 1 lists all of the inclusion and exclusion criteria in detail.

Table 1. Selection criteria.

Inclusion Criteria	Exclusion Criteria
English language.	Articles published in languages other than English
Articles published between January 2019 and February 2025.	All study types except randomized clinical trials, in-vitro studies, and cohort studies were excluded.
Participants with missing teeth.	artificial intelligence tools in the identification of other dental/oral structures.
Artificial intelligence-guided implant surgery.	Studies for which only abstracts are available, studies that deal with methods other than artificial intelligence, and artificial intelligence tools under testing.

Exposure and outcome

In the current study, the exposure was bone density in implant surgery using an artificial intelligence tool. The outcome was the accuracy of identification. The focused PICO (Population (P), Intervention (I), Comparison (C), and Outcome (O)) question for the present study was “What is the accuracy (outcome) of artificial intelligence tools (Intervention) in detecting bone density in implant surgery in Participants with missing teeth (Participant/population)?”

Information sources and search strategy

The relevant published literature was gathered through a systematic search of four electronic databases: Web of Science, Scopus,

MEDLINE/PubMed, and Cochrane. The developed PICO question served as the basis for the search terms. Only articles published in English within the previous five years (January 2019 and February 2025) were included in the search. Animal studies were excluded from the analysis. Table 2 provides specifics regarding the search approach. Based on the database's requirements, a few minor adjustments were made to the search strings. The bibliographies of chosen studies and other review articles were manually reviewed after searching the grey literature to ensure no pertinent articles were overlooked.

Strategy and search terms for the electronic databases

Table 2. The approach and keywords for international databases.

Database	Search Terms and Strategy
MEDLINE (PubMed)	(((((((((("Dental Implants"[Mesh]) OR "Dental Prosthesis"[Mesh]) OR "Dental Implantation"[Mesh]) OR ("Oral Surgical Procedures"[Mesh] OR "Surgery, Oral"[Mesh])) AND ("Surgery, Computer-Assisted"[Mesh] OR "Image Processing, Computer-Assisted"[Mesh] OR "Diagnosis, Computer-Assisted"[Mesh] OR "Radiographic Image Interpretation, Computer-Assisted"[Mesh] OR "Computer-Aided Design"[Mesh] OR "Cone-Beam Computed Tomography"[Mesh])) AND "Artificial Intelligence"[Mesh]) OR "Machine Learning"[Mesh]) OR "Predictive Learning Models"[Mesh]) AND "Data Accuracy"[Mesh]) OR "Sensitivity and Specificity"[Mesh]) AND "Humans"[Mesh].
Scopus	("Dental Implants" OR "Dental Prosthesis" OR "Dental Implantation" OR ("Oral Surgical Procedures" OR "Surgery, Oral") AND ("Surgery, Computer-Assisted" OR "Image Processing, Computer-Assisted" OR "Diagnosis, Computer-Assisted" OR "Radiographic Image Interpretation, Computer-Assisted" OR "Computer-Aided Design" OR "Cone-Beam Computed Tomography")) AND ("Artificial Intelligence" OR "Machine Learning" OR "Predictive Learning Models") AND ("Data Accuracy" OR "Sensitivity and Specificity") AND ("Humans" OR "missing teeth").
Web of Science	#1 (population) 'dental implantation' OR 'dental implants' OR 'bone density' OR 'implant surgery' #2 (intervention) 'artificial intelligence' OR 'machine learning' #3 (outcome) 'sensitivity and specificity' OR 'Accuracy' OR 'sensitivity' OR 'specificity'
Cochrane	#1 MeSH descriptor: [Dental Implants] #2 Implant surgery #3 Bone density #4 MeSH descriptor: [Artificial Intelligence] #5 MeSH descriptor: [Machine Learning] #6 Deep learning #7 MeSH descriptor: [Sensitivity and Specificity] #8 Accuracy #9 Sensitivity #10 Specificity #1 OR #2 OR #3 AND #4 OR #5 OR #6 AND #7 OR #8 OR #9 OR #10

Selection, data collection, screening and data extraction

After two blind, independent researchers examined the data from the chosen studies, a third researcher provided a summary. The research team utilized a pre-made form to gather the data, which contained sections such as the first author's name, the year of publication, the study design, the number of patients, participant characteristics, Surgical templates, and data.

Quality assessment, statistical heterogeneity, and data analysis

The bias of the prediction models is assessed using the PROBAST (Prediction Model Risk of Bias Assessment Tool).^[15] PROBAST comprises four domains: participants, predictors, outcomes, and assessment. Based on how each PROBAST checklist item was answered, each domain was assigned a risk of bias rating (high, low, or unclear). I^2 and the chi-square test ($\times 2$) are used to assess study heterogeneity. Four levels of I^2 heterogeneity were examined: low ($\leq 25\%$), moderate (25-50%), substantial (50-75%), and considerable ($\geq 75\%$). The accuracy of AI was used as an effect size in a fixed-effects model and inverse-variance methods, with 95% confidence intervals (CI). A significance of less than 0.05 was considered. All data analysis was performed using Stata.v18 software.

3. Results

Identification and screening

The databases were searched electronically, and 312 results were shown. The titles of 312 articles were examined, and their eligibility was verified using inclusion and exclusion criteria after 61 articles were eliminated as duplicates. A total of 198 articles were carefully reviewed by two independent blind authors based on the inclusion and exclusion criteria. One hundred thirteen articles were not eligible to be included in the study and were excluded at this stage. For full-text review, 85 articles were chosen. Irrelevant studies, incomplete data, and the lack of artificial intelligence utilization in implant planning were excluded at this stage. Ultimately, eleven articles were included in the study. Upon manually searching the bibliographies of the chosen studies and other review articles, no pertinent articles that satisfied the selection criteria were discovered. (Fig. 1).

Study characteristics

Table 3 displays the characteristics of the studies. Five thousand three hundred seventy-one implant images were selected for analysis, and surgical fully guided templates were designed by using an AI implant planning software program.

Quality assessment of included studies

As shown in Table 4, all studies were of high quality (low risk of bias).

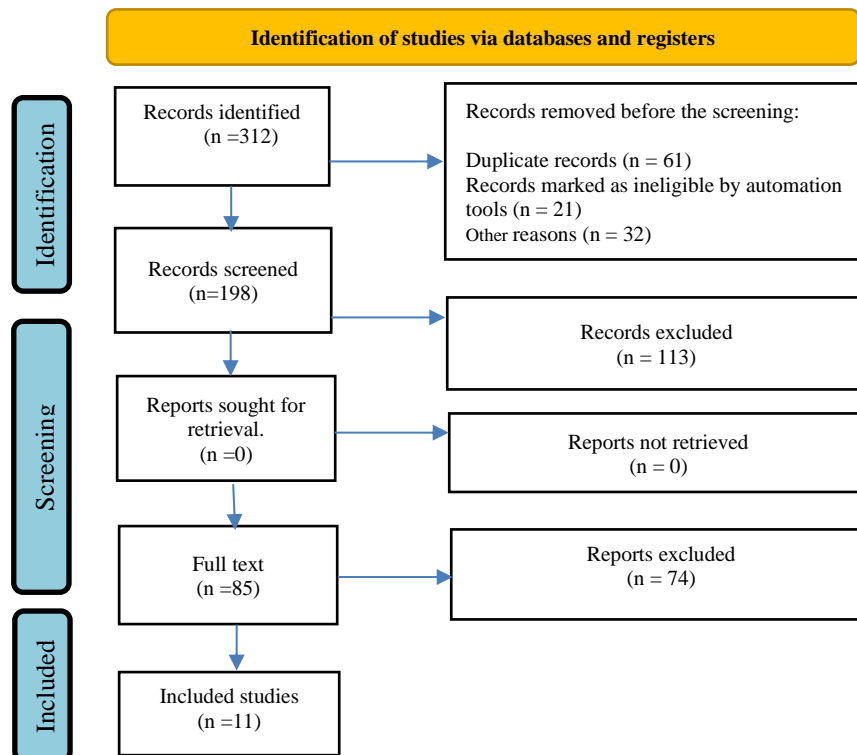


Fig. 1. PRISMA 2020 Checklist.

Table 3. Study characteristics and method of the included studies.

No.	Study. Years	Study Design	Sample Size	Participants	Surgical Templates	Data
1	Chen et al., 2024 ^[10]	In vitro	10	Missing mandibular left first molars	AI implant planning software program	3-dimensional printing
2	Yang et al., 2023 ^[16]	Retrospective	1366	Patients under implants	AI implant planning software program	2-dimensional printing
3	Moufti et al., 2023 ^[17]	Retrospective	43	edentulous mandibular bone for implant planning	AI implant planning (CNN architecture)	CBCT
4	Vinayahalingam et al., 2023 ^[18]	Retrospective	1750	Patients under implants	AI implant planning (CNN architecture)	casts scans
5	Oliveira-Santos et al., 2023 ^[19]	Retrospective	27	Patients under implants	AI implant planning (CNN architecture)	CBCT
6	Jindanil et al., 2023 ^[20]	Retrospective	200	Patients under implants	AI implant planning (CNN architecture)	CBCT
7	Sakai et al., 2023 ^[21]	Retrospective	60	Patients under implants	AI implant planning (CNN architecture)	CBCT
8	Lyakhov et al., 2022 ^[22]	Case-control	1626	Patients under implants	AI implant planning (CNN architecture)	3-dimensional printing
9	Alsomali et al., 2022 ^[23]	Retrospective	34	patients who had a CBCT examination performed wearing a radiographic stent for implant treatment planning.	AI implant planning (R-CNN)	CBCT
10	Roongruangsilp et al., 2021 ^[24]	Retrospective	184	Patients under implants	AI implant planning (R-CNN algorithm)	CBCT
11	Kurt Bayrakdar et al., 2021 ^[25]	Retrospective	75	Patients under implants	AI implant planning (CNN architecture)	CBCT

Table 4. Bias assessments of included studies according to PROBAST.

Study. Years	Risk of Bias				Overall
	Participants	Predictors	Outcomes	Assessment	
Chen et al., 2024 ^[10]	★	★	★	★	low
Yang et al., 2023 ^[16]	★	★	★	★	low
Moufti et al., 2023 ^[17]	★	★	★	★	low
Vinayahalingam et al., 2023 ^[18]	★	★	★	★	low
Oliveira-Santos et al., 2023 ^[19]	★	★	★	★	low
Jindanil et al., 2023 ^[20]	★	★	★	★	low
Sakai et al., 2023 ^[21]	☆	★	★	★	low
Lyakhov et al., 2022 ^[22]	★	★	★	★	low
Alsomali et al., 2022 ^[23]	★	★	★	★	low
Roongruangsilp et al., 2021 ^[24]	★	★	★	★	low
Kurt Bayrakdar et al., 2021 ^[25]	★	★	★	★	low

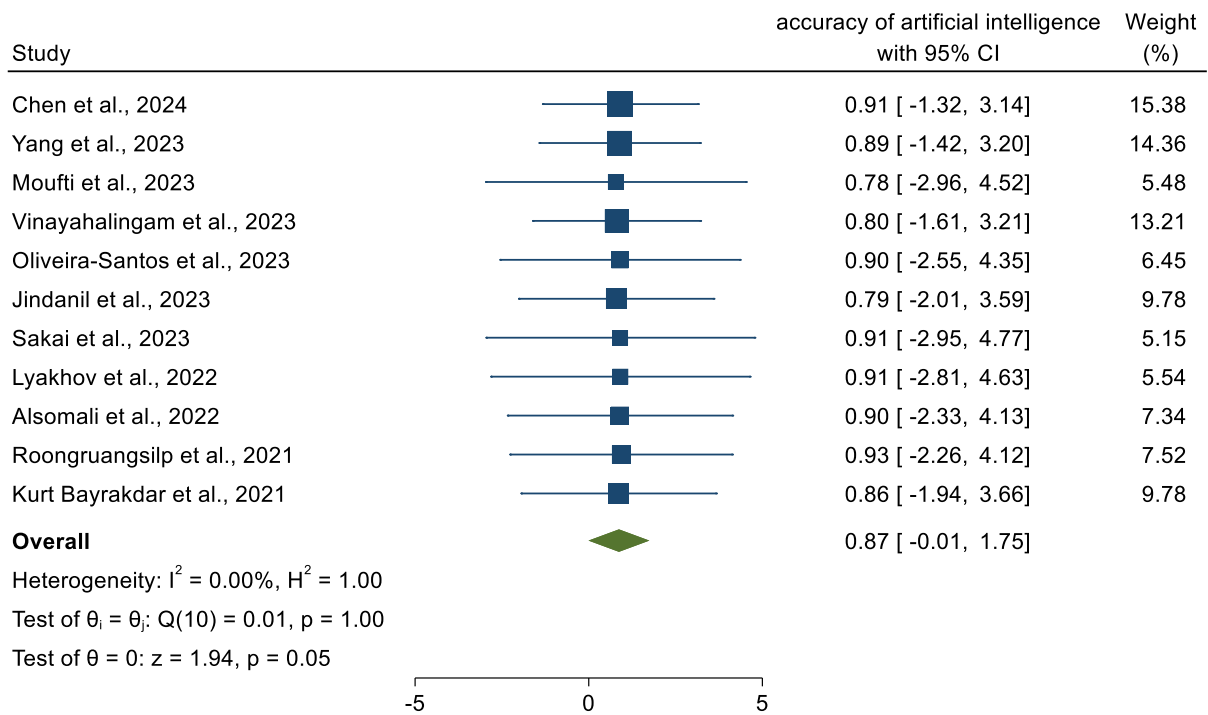
Black stars (★) to signify that a study satisfactorily meets a specific criterion.

White stars (☆) indicate that a criterion is not met.

Accuracy of artificial intelligence-guided implant surgery

The accuracy of artificial intelligence-guided implant surgery was 87% (ES 0.87 95% CI; -0.01, 1.75); the accuracy of the AI-assisted designed

implant template was high (Fig. 2). The I^2 statistic was 0% ($p = 1.00$), indicating low heterogeneity (Fig. 2 and 3).



Fixed-effects inverse-variance model

Fig. 2. A forest plot showed the accuracy of artificial intelligence-guided implant surgery.

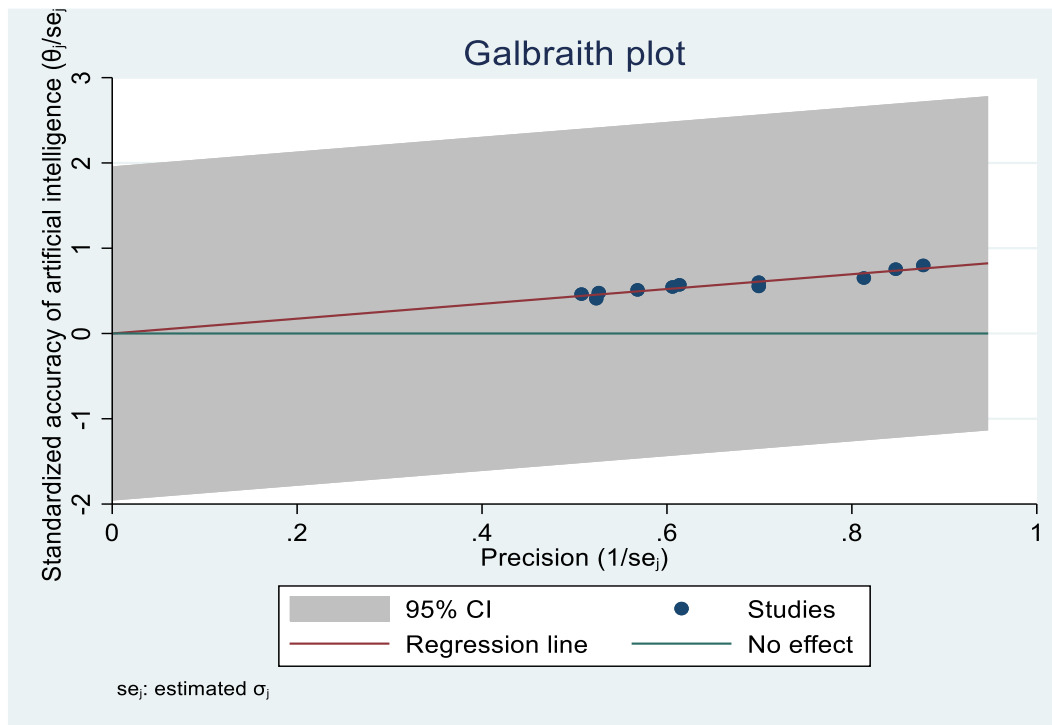


Fig. 3. The Galbraith plot showed low heterogeneity among the selected studies.

Bone density

According to meta-regression, in guided implant surgery, a higher bone density increased the risk of angular and implant apex deviations (Table 5).

Publication bias

The funnel plot showed a proportional distribution of studies, with those on the line, allowing for visible symmetry. The result of Egger's regression test also showed a non-significant p-value for bias ($p > 0.01$). (Fig. 4).

Table 5. Meta-regression.

Meta_es		Coefficient	Standard Error	z	P> z
Higher Bone Density	Apical	.66	9.58	0.07	0.09
	Angular Deviations	-.30	5.7	-0.05	0.04

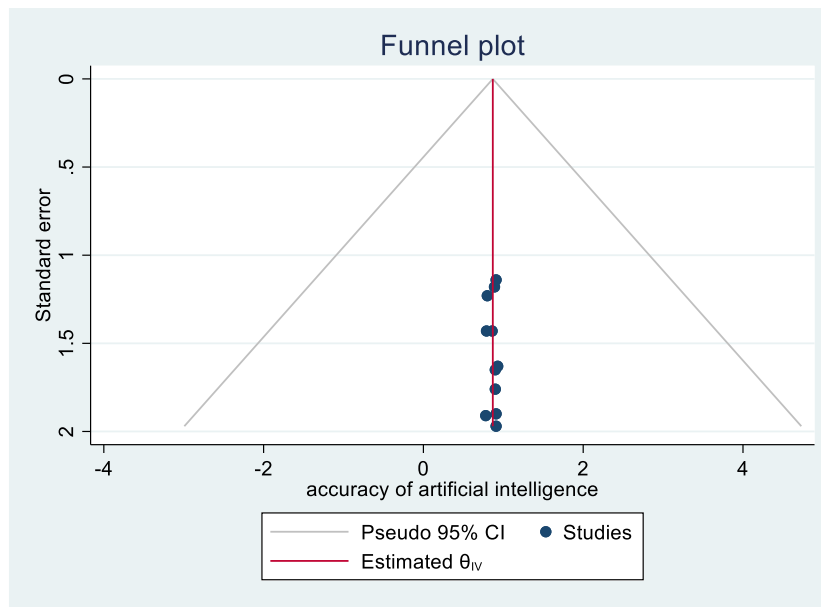


Fig. 4. Funnel plot of standard error by standard effect size.

4. Discussion

Diagnostic procedures are an essential component of dental practice. The first step to a successful and individualized course of treatment is a precise diagnosis and the identification of anatomic structures.^[26] In the field of oral implant rehabilitation, it is crucial to place the implant away from neural structures to prevent intraoperative and postoperative complications.^[27] According to the findings of the present study and the selected studies, implant surgery is highly accurate when performed with the aid of artificial intelligence. Additionally, meta-regression analysis revealed a direct relationship between the bone density of the implant area and the accuracy of implant surgery, indicating that higher bone density is associated with greater apex and angular deviation of the implant. Studies have shown that more deviations can occur in patients with higher bone density, which increases the lateral vibration of the mold during implant surgery.^[10, 28, 29] According to the findings of a study, more bone density leads to an increase in the possibility of pattern rotation.^[30] The detection model and deep learning algorithm played a significant role in the success of AI-assisted guided implant surgery. By identifying the reference points, the detection model can automatically determine the anatomy of the implant region. The software application can identify the optimal implant location in conjunction with the deep learning algorithm. Clinically acceptable deviations were found in the AI-assisted implant surgical template, according to systematic reviews and meta-analyses.^[27, 31, 32] AI systems have reportedly been able to precisely identify bone density from imaging data in recent years, which can aid in the diagnosis of osteoporosis.^[33] Future research can assess whether the AI-assisted implant planning software program can synchronously analyze the ideal implant

position and bone density of the implant area by incorporating bone density measurement into the algorithm. This will help further optimize the AI software program. Once it has detected the high bone density, the AI software can advise physicians to use anchor micro-screws or add more supporting teeth to stabilize the surgical template.

5. Conclusion

Based on the findings of the present study, the use of artificial intelligence in implant planning is highly accurate. However, further studies are needed to confirm the evidence, as the number of articles is limited, and the study designs vary. Therefore, to confirm the evidence, it is necessary to conduct studies with a clinical and cohort design to provide stronger results. Additionally, meta-regression revealed that in guided implant surgery, bone density should be closely monitored, as higher bone density can lead to angular deviation of the implant and its apex. Therefore, in guided implant surgery, bone density can affect the accuracy of artificial intelligence.

Conflict of Interest

The authors declared that there is no conflict of interest.

Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

- [1] Dioguardi M, Spirito F, Quarta C, Sovereto D, Basile E, Ballini A, et al. Guided dental implant surgery: Systematic review. *Journal of Clinical Medicine*. 2023;12(4):1490. <https://doi.org/10.3390/jcm12041490>.

- [2] Yogui FC, Verri FR, de Luna Gomes JM, Lemos CA, Cruz RS, Pellizzer EP. Comparison between computer-guided and freehand dental implant placement surgery: A systematic review and meta-analysis. *International journal of oral and maxillofacial surgery*. 2021;50(2):242-50. <https://doi.org/10.1016/j.ijom.2020.08.004>.
- [3] Pozzi A, Tallarico M, Marchetti M, Scarfò B, Esposito M. Computer-guided versus free-hand placement of immediately loaded dental implants: 1-year post-loading results of a multicentre randomised controlled trial. *Eur J Oral Implantol*. 2014;7(3):229-42.
- [4] Verbruyssens M, Coucke W, Naert I, Jacobs R, Teughels W, Quirynen M. Depth and lateral deviations in guided implant surgery: An RCT comparing guided surgery with mental navigation or the use of a pilot - drill template. *Clinical Oral Implants Research*. 2015;26(11):1315-20. <https://doi.org/10.1111/clr.12460>.
- [5] Wong SH, Al-Hasani H, Alam Z, Alam A. Artificial intelligence in radiology: how will we be affected?. *European radiology*. 2019;29:141-3. <https://doi.org/10.1007/s00330-018-5644-3>.
- [6] Kulkarni S, Seneviratne N, Baig MS, Khan AH. Artificial intelligence in medicine: where are we now?. *Academic radiology*. 2020;27(1):62-70. <https://doi.org/10.1016/j.acra.2019.10.001>.
- [7] Saghiri MA, Asgar K, Boukani KK, Lotfi M, Aghili H, Delvarani A, et al. A new approach for locating the minor apical foramen using an artificial neural network. *International endodontic journal*. 2012;45(3):257-65. <https://doi.org/10.1111/j.1365-2591.2011.01970.x>.
- [8] Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asgar K. The reliability of artificial neural network in locating minor apical foramen: a cadaver study. *Journal of Endodontics*. 2012;38(8):1130-4. <https://doi.org/10.1016/j.joen.2012.05.004>.
- [9] Johari M, Esmacili F, Andalib A, Garjani S, Saberhari H. Detection of vertical root fractures in intact and endodontically treated premolar teeth by designing a probabilistic neural network: an ex vivo study. *Dentomaxillofacial Radiology*. 2017;46(2):20160107. <https://doi.org/10.1259/dmfr.20160107>.
- [10] Chen Z, Liu Y, Xie X, Deng F. Influence of bone density on the accuracy of artificial intelligence-guided implant surgery: An in vitro study. *The Journal of prosthetic dentistry*. 2024;131(2):254-61. <https://doi.org/10.1016/j.prosdent.2021.07.019>.
- [11] Tatakis DN, Chien HH, Parashis AO. Guided implant surgery risks and their prevention. *Periodontology 2000*. 2019;81(1):194-208. <https://doi.org/10.1111/prd.12292>.
- [12] Naziri E, Schramm A, Wilde F. Accuracy of computer-assisted implant placement with insertion templates. *GMS Interdisciplinary plastic and reconstructive surgery DGPW*. 2016;5:1-16. <https://doi.org/10.3205/ipsr000094>.
- [13] El Kholy K, Janner SF, Schimmel M, Buser D. The influence of guided sleeve height, drilling distance, and drilling key length on the accuracy of static Computer - Assisted Implant Surgery. *Clinical implant dentistry and related research*. 2019;21(1):101-7. <https://doi.org/10.1111/cid.12705>.
- [14] Antoniou GA, Riga CV, Mayer EK, Cheshire NJ, Bicknell CD. Clinical applications of robotic technology in vascular and endovascular surgery. *Journal of vascular surgery*. 2011;53(2):493-9. <https://doi.org/10.1016/j.jvs.2010.06.154>.
- [15] van Boekel AM, van der Meijden SL, Arbous SM, Nelissen RG, Veldkamp KE, Nieswaag EB, et al. Systematic evaluation of machine learning models for postoperative surgical site infection prediction. *PLoS one*. 2024;19(12):e0312968. <https://doi.org/10.1371/journal.pone.0312968>.
- [16] Yang S, Li A, Li P, Yun Z, Lin G, Cheng J, et al. Automatic segmentation of inferior alveolar canal with ambiguity classification in panoramic images using deep learning. *Heliyon*. 2023;9(2):e13694. <https://doi.org/10.1016/j.heliyon.2023.e13694>.
- [17] Moufti MA, Trabulsi N, Ghousheh M, Fattal T, Ashira A, Danishvar S. Developing an artificial intelligence solution to autosegment the edentulous mandibular bone for implant planning. *European Journal of Dentistry*. 2023;17(04):1330-7. <https://doi.org/10.1055/s-0043-1764425>.
- [18] Vinayahalingam S, Kempers S, Schoep J, Hsu TM, Moin DA, van Ginneken B, et al. Intra-oral scan segmentation using deep learning. *BMC Oral Health*. 2023;23(1):643. <https://doi.org/10.1186/s12903-023-03362-8>.
- [19] Oliveira-Santos N, Jacobs R, Picoli FF, Lahoud P, Niclaes L, Groppo FC. Automated segmentation of the mandibular canal and its anterior loop by deep learning. *Scientific reports*. 2023;13(1):10819. <https://doi.org/10.1038/s41598-023-37798-3>.
- [20] Jindanil T, Marinho-Vieira LE, de-Azevedo-Vaz SL, Jacobs R. A unique artificial intelligence-based tool for automated CBCT segmentation of mandibular incisive canal. *Dentomaxillofacial Radiology*. 2023;52(8):20230321. <https://doi.org/10.1259/dmfr.20230321>.
- [21] Sakai T, Li H, Shimada T, Kita S, Iida M, Lee C, et al. Development of artificial intelligence model for supporting implant drilling protocol decision making. *Journal of prosthodontic research*. 2023;67(3):360-5. https://doi.org/10.2186/jpr.JPR_D_22_00053.
- [22] Lyakhov PA, Dolgalev AA, Lyakhova UA, Muraev AA, Zolotayev KE, Semerikov DY. Neural network system for analyzing statistical factors of patients for predicting the survival of dental implants. *Frontiers in Neuroinformatics*. 2022;16:1067040. <https://doi.org/10.3389/fninf.2022.1067040>.
- [23] Alsomali M, Alghamdi S, Alotaibi S, Alfadda S, Altwaijry N, Alturaiki I, et al. Development of a deep learning model for automatic localization of radiographic markers of proposed dental implant site locations. *The Saudi Dental Journal*. 2022;34(3):220-5. <https://doi.org/10.1016/j.sdentj.2022.01.002>.
- [24] Roongruangsilp P, Khongkhunthian P. The learning curve of artificial intelligence for dental implant treatment planning: a descriptive study. *Applied Sciences*. 2021;11(21):10159. <https://doi.org/10.3390/app112110159>.
- [25] Kurt Bayrakdar S, Orhan K, Bayrakdar IS, Bilgir E, Ezhov M, Gusarev M, et al. A deep learning approach for dental implant planning in cone-beam computed tomography images. *BMC medical imaging*. 2021;21(1):86. <https://doi.org/10.1186/s12880-021-00618-z>.
- [26] Macri M, D'Albis G, D'Albis V, Timeo S, Festa F. Augmented reality-assisted surgical exposure of an impacted tooth: a pilot study. *Applied Sciences*. 2023;13(19):11097. <https://doi.org/10.3390/app131911097>.
- [27] Macri M, D'Albis V, D'Albis G, Forte M, Capodiferro S, Favia G, et al. The role and applications of Artificial Intelligence in Dental Implant Planning: a systematic review. *Bioengineering*. 2024;11(8):778. <https://doi.org/10.3390/bioengineering11080778>.
- [28] Khaohoen A, Powcharoen W, Sornsuan T, Chaijareenont P, Rungsiyakull C, Rungsiyakull P. Accuracy of implant placement with computer-aided static, dynamic, and robot-assisted surgery: a systematic review and meta-analysis of clinical trials. *BMC Oral Health*. 2024;24(1):359. <https://doi.org/10.1186/s12903-024-04033-y>.

- [29] Cassetta M, Stefanelli LV, Giansanti M, Di Mambro A, Calasso S. Depth deviation and occurrence of early surgical complications or unexpected events using a single stereolithographic surgi-guide. *International journal of oral and maxillofacial surgery*. 2011;40(12):1377-87. <https://doi.org/10.1016/j.ijom.2011.09.009>.
- [30] Cassetta M, Di Mambro A, Giansanti M, Stefanelli LV, Cavallini C. The intrinsic error of a stereolithographic surgical template in implant guided surgery. *International journal of oral and maxillofacial surgery*. 2013;42(2):264-75. <https://doi.org/10.1016/j.ijom.2012.06.010>.
- [31] Tahmaseb A, Wu V, Wismeijer D, Coucke W, Evans C. The accuracy of static computer - aided implant surgery: A systematic review and meta - analysis. *Clinical oral implants research*. 2018;29:416-35. <https://doi.org/10.1111/clr.13346>.
- [32] Bover-Ramos F, Viña-Almunia J, Cervera-Ballester J, Peñarocha-Diogo M, García-Mira B. Accuracy of Implant Placement with Computer-Guided Surgery: A Systematic Review and Meta-Analysis Comparing Cadaver, Clinical, and In Vitro Studies. *International Journal of Oral & Maxillofacial Implants*. 2018;33(1). <https://doi.org/10.11607/jomi.5556>.
- [33] Hwang JJ, Lee JH, Han SS, Kim YH, Jeong HG, Choi YJ et al. Strut analysis for osteoporosis detection model using dental panoramic radiography. *Dentomaxillofacial Radiology*. 2017;46(7). <https://doi.org/10.1259/dmfr.20170006>.

How to Cite this Article: Mardani Z, Salehi A, Jabbarpor F, Azizi B. Diagnostic Accuracy of Artificial Intelligence in Bone Density in Implant Surgery: A Systematic Review and Meta-analysis. *International Journal of Scientific Research in Dental and Medical Sciences*. 2025;7(2):70-77. <https://doi.org/10.30485/IJSRDMS.2025.510789.1645>.