



Newer Technological Advances: A Step Towards Better Dental Care: A systematic review

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Abstract:

Background: Advanced technologies have drastically impacted the practice of dentistry in order to treat patients more effectively and efficiently.

Objective: The goal of this systematic review was to give a thorough overview of the most widely applied advanced technology and its uses in dentistry.

Materials and Methods: This assessment adhered to the Preferred Reporting Items for Systematic Review (PRISMA) guidelines and its extension, PRISMA-S, which focuses on reporting literature searches in systematic reviews. The aim was to identify the prevalent applications of advanced technology in dentistry. To achieve this, search engines were employed to extract pertinent data from databases, such as PubMed, Web of Science, and Scopus. The systematic review was conducted in an Indian dental institution after registering in PROSPERO. According to database searches, the most popular advanced technologies utilized by dentists from 2013 to 2023 were included.

Results: Only 30 publications that offered comparative and systematic reviews of cutting-edge dental technology were selected from all the eligible articles out of 527 identified articles. Following the fulfillment of the inclusion criteria, this systematic review incorporated all research studies pertinent to artificial intelligence and machine learning (n=10), robotics in dentistry (n=10), and 3D printing (n=10).

Conclusion: Integrating new technologies into traditional dental practices has the potential to not only enhance patient outcomes but also elevate clinician satisfaction and career prospects.

Keywords: Artificial intelligence, Machine learning, 3D Printing, Robotic dentistry, Preferred Reporting Items for Systematic Review, PROSPERO.

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1. INTRODUCTION

The advent of digital human-centered automation presents a significant opportunity to revolutionize dentistry, ushering in a new era enabled by robotics, machine learning, and artificial intelligence. Our knowledge of disease aetiology will grow as a result of the use of digital technology, which will also help with risk assessment methods, diagnosis, disease prediction, and treatment outcomes [1-3].

The inevitable result of technological advancement is that more and more manual labour will be automated over the coming decades. Digital process redesign is being promoted by researchers and practitioners as a useful strategy to lower practice variance and raise the standard of care in general [4-6].

These innovative technologies are now being taught in dental schools, giving students the opportunity to get hands-on practice. As a result, students gain a more profound understanding of the subject matter, equipping them to deliver optimal treatment to their future patients [7-9].

By delegating tasks to robot assistants, staff members can allocate their time to activities that require human interaction, such as engaging directly with patients or fulfilling duties demanding high cognitive abilities. Robot assistants, being tireless and capable of endlessly repeating workflows, enable staff members to focus on these essential aspects of their roles. The application of robotic technology in dentistry schooling is another intriguing topic. Universities use advanced simulation, mechanical device interface, and occasionally full-body robotics individuals to train students in fundamentally crucial abilities for future dentists before they have actual patient contact [10-13].

But recently, healthcare robots have been used in several clinical settings alongside those in the practice of dentistry. Modern robotics technology has advanced quickly. Incorporating smart robotic technology into dental clinics, particularly as dental assistants, has the potential to significantly enhance the existing technical infrastructure. Human factors, such as the mental and physical strain experienced by staff assistants during prolonged shifts demanding constant attention or the lack of ergonomic work environments, are among the primary motivating factors driving this initiative [14-17].

Technological advancements have revolutionized dental care, making it more precise, safe, and patient-friendly. Examples include digital X-rays and the advent of 3D printing, which has notably impacted dental treatment. Three-dimensional printing has revolutionized the fabrication of dental prosthetic restorations like crowns and bridges. Dentists can now utilize highly accurate 3D-printed replicas of a patient's teeth to plan and create customized dental restorations. This approach has significantly reduced the time required for fabrication, enhancing procedure efficiency and cost-effectiveness [18-20].

There are a number of supporting technologies, such

as robotics, AI, and ML, that could help design new dental procedures. Future robotics and dentistry collaborations have a wide range of potential applications. Opportunities exist in robotics, machine learning, artificial intelligence (AI), and dentistry that should be targeted to take advantage of new technology [21-23].

The word machine learning (ML) encompasses several approaches for using potentially enormous quantities of data to learn from experience and improve oneself. It sets itself apart from traditional artificial intelligence (AI), which focuses mostly on logical thinking, knowledge representation, and planning and search issues [24-26].

Dentistry is heading further regarding the future of data-driven and robot-assisted healthcare. ML and AI are still not entirely applied to dental research. ML will advance diagnostic procedures, simplify treatment planning, lower the rate of treatment errors, and ultimately boost the efficiency of the entire healthcare system. The rationale of this review is to identify the new dental professionals who need to be conversant with technological advancements and how they can apply them to dentistry [27-30].

The goal of this systematic review is to give a thorough overview of the most widely applied modern technology and its applications in dentistry.

2. MATERIALS AND METHODS

An Indian institute conducted a systematic review using a rigorous, structured process that was in line with international standards. The specific steps needed to carry out a systematic review procedure are listed below.

2.1. Formulating the Research Question

The research question was formulated using the PICO (Population, Intervention, Comparison, Outcome) framework, and a preliminary search was conducted to ensure that the question had not already been addressed. (PICO Search: P- Technology in dentistry; I- Advanced digital technology; C-Standard methods; O- Applications in dentistry, widely used digital technology).

2.2. Developing a Protocol

The study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) on May 21, 2023, under the registration ID CRD42023425451 to ensure transparency. Initially, the methods, inclusion and exclusion criteria, data extraction, and analysis plan for conducting the systematic review were outlined.

2.3. Eligibility Criteria for Study

The current systematic review included English-language scientific articles that met the following criteria: randomized controlled trials comparing advanced digital technology in dentistry; controlled clinical trials evaluating the impact of digital technology in dentistry; and original study papers, case reports, and systematic reviews focusing on digital technology applications in dentistry. Research articles in languages other than English were excluded, as were studies that did not correspond with the

review's objectives, technical notes, brief communication, editorial letters, and mini-reviews.

2.4. Literature Search

The search technique used in this systematic review sought to discover pertinent articles published between 2013 and 2023 which addressed research questions associated with the review's aims. The search was last conducted in August 2023. The search parameters were designed to focus on the utilization of advanced technology in dental healthcare and its applications in dental practice.

Three reviewers individually searched for literature papers relevant to advanced technology and its applications in dentistry. Publications relevant to the subject of this targeted systematic overview were identified using digital databases, such as PubMed, Web of Science, and Scopus.

We generated a list of keywords derived from available research publications and our understanding of the topic. The following keywords were used: "advanced technology"/"modern technology" "artificial intelligence/ machine learning"/ robotic dentistry" and "3D technology" in dental health care professions and its applications in dental practice.

This set of terms was subsequently employed as a search query in databases, such as Scopus, Web of Science, and PubMed. This method facilitated the refinement of primary search criteria, focusing on identifying crucial elements associated with cutting-edge technology in oral healthcare. The Boolean operators, such as AND/OR/NOT, were used in PubMed to narrow or extend the search scope to cover every potential publication. The search terms utilized in the Scopus, Web of Science, and PubMed databases were:

Advanced [All Fields] AND ("technology"[MeSH Terms] OR "technology"[All Fields]) AND ("dentistry"[MeSH Terms] OR "dentistry"[All Fields]) AND "three-dimensional"[All Fields] OR "three-dimensional printing"[All Fields] OR ("3d"[All Fields] AND "printing"[All Fields]) OR "3d printing"[All Fields]) AND ("dentistry"[MeSH Terms] OR "dentistry"[All Fields]) AND (("artificial intelligence"[MeSH Terms] OR "artificial"[All Fields] AND "intelligence"[All Fields]) OR "artificial intelligence"[All Fields]) AND ("dentistry"[MeSH Terms] OR "dentistry"[All Fields]) AND ("2018/05/27"[PDat]: "2023/05/25"[PDat]) AND (("machine learning"[MeSH Terms] OR ("machine"[All Fields] AND "learning"[All Fields]) OR "machine learning"[All Fields]) AND ("dentistry"[MeSH Terms] OR "dentistry"[All Fields])) AND ("2018/05/27"[PDat]: "2023/05/25"[PDat]) AND (("robotics"[MeSH Terms] OR "robotics"[All Fields]) AND ("dentistry"[MeSH Terms] OR "dentistry"[All Fields])) AND ("2018/05/27"[PDat]: "2023/05/25"[PDat]). The sequence of the search strategy is explained in a flow chart by following the PRISMA guidelines (Fig. 1).

2.5. Screening and Selection

Once the articles were retrieved, we meticulously selected the appropriate research papers for our systematic review. Two examiners extracted data using procedures described in public sources, such as journal papers and clinical trials, which provide vital information regarding the methods and outcomes of the articles that were analyzed. The information gathered was used to generate outlines for the figures and tables that were included in the evaluation, as well as assist in developing data-gathering forms.

2.6. Data Extraction

The two reviewers meticulously developed a pre-tested data extraction form on "Newer Technological Advances: A step towards better dental care" in order to perform a systematic review. Creating an extensive form to record study specifics such as identification, design, population, intervention, outcomes, results, and quality assessment was part of the data extraction process. The form was pre-tested on a few studies to make sure it successfully collected all required data. After extracting data independently, two reviewers compared it and used a consensus meeting to settle any inconsistencies. Next, a precise entry of the extracted data into a central database was made. This systematic procedure guaranteed dependability and consistency, offering a strong basis for the systematic review.

2.7. Quality Assessment

In this systematic study, the Cochrane Collaboration's Risk of Bias Tool was used to evaluate possible risks. Using this risk assessment technique allowed us to write articles of excellent quality with strong findings. These parameters were used to assess the subjective potential for bias in appropriate research and assigned to one of the three categories depending on variables, such as a series generation, distribution concealment, participants blinding, blinding result assessment, which is unfinished outcome information, and selective results reporting. The quality assessment was conducted independently by two reviewers, and in case of any discrepancies, it was resolved through discussion.

The study was analyzed using Jira™ data analysis software. The quality of the study was independently assessed using the Critical Appraisal Skills Programme (CASP) checklists. Two independent observers performed the final data extraction, and their work was properly documented. A Kappa value of 0.75 indicated strong inter-observer concordance.

2.8. Data Synthesis

The distinguishing characteristics of the research papers were described and included in this systematic review, and the results from individual investigations were summarized.

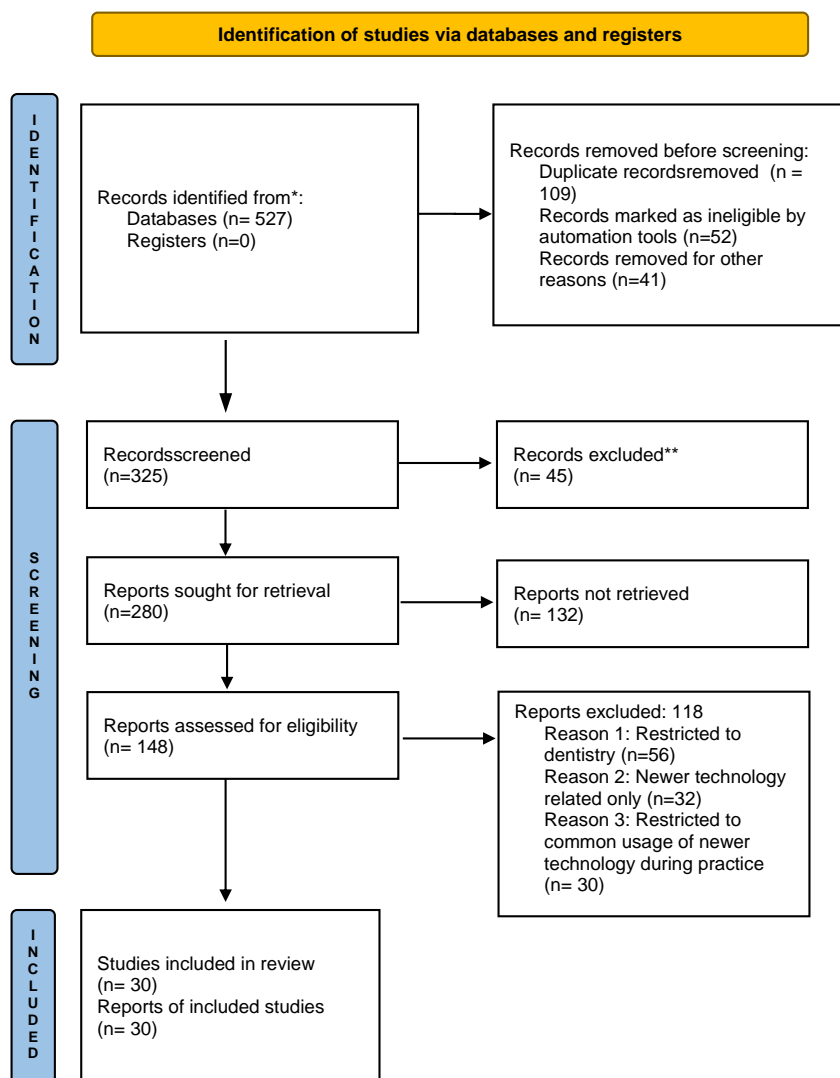


Fig. (1). Illustrates the flow diagram of the study selection process in accordance with the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) guidelines.

2.9. Reporting

Following the guidelines of PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) and its extension, PRISMA-S, this systematic review focused on advanced technology and its applications in dentistry. The field of dentistry has been notably influenced by the integration of advanced technologies. Hence, this systematic review aimed to offer a comprehensive overview of the predominant advanced technologies utilized in dentistry and their effects on treatment outcomes.

3. RESULTS

An initial keyword search yielded a total of 527 items. Following preliminary filtering, 325 papers remained for review, aligning with the goals of the systematic review. Among these, 148 publications were deemed relevant to

the review's criteria or goals. From the eligible articles, only 30 publications offering comparative and systematic reviews of cutting-edge dental technology were selected. The included research papers and reviews were categorized based on their study goal and significance. Tables 1, 2 and 3 outline the characteristics of the research publications included in this systematic review.

Following the guidelines outlined in the Critical Appraisal Skills Programme checklist (CASP), the risk of bias, including selective reporting and publication bias, can be evaluated, which may impact the overall data set. Following data extraction, a quality assessment using the checklist provided by CASP was performed to determine the advantages and disadvantages of the identified studies' procedures. The evaluation centered on the reliability, transparency, and standardization of the research examined, which was carried out separately using the CASP checklist, as shown in Table 4.

Table 1. Summarizes the latest research on 3D printing and its applications in dentistry [8-10, 14, 18, 20, 21, 23, 24, 26].

S.No	Citation No	Conclusive Statements	Dental Specialty
1	8	Based on the average misfit value reported in the literature (150 µm), all intraoral scanners demonstrate the ability to produce a digital full implant impression <i>in vitro</i> . However, the 3D distance analysis indicated that only the Primescan and iTero exhibited negligible systematic error sources.	Implantology
2	9	Both 3D-printed multilayer mouthguards gained patient approval and displayed a fit that was clinically acceptable.	Orthodontics
3	10	According to the results, it may be possible to use the produced 3D-printed teeth to practice caries eradication in preclinical dentistry education.	Conservative dentistry
4	14	20% of patients preferred and utilised digital dentures on a daily basis, despite the fact that patient satisfaction or quality of life may be slightly lower with DDs than with CDs. DDs created through 3D printing may, therefore be as useful and effective as CDs.	Prosthodontics
5	18	Before having their lips repaired surgically, newborns with unilateral complete cleft lip and palate (UCLP) can have their maxillary arch dimensions (MADs) improved with the newly invented 3D-printed nasoalveolarmoulding (D-NAM) appliance.	Pedodontics
6	20	Overdentures made using 3D printing could be an alternative to those made using more traditional methods. This study serves as a first step and proof of concept for the prospective use of 3D-printed dentures in the future.	Prosthodontics
7	21	In the context of this study, utilising a 3D-printed model to practice obturation did not significantly enhance dentistry students' obturation abilities.	Endodontics
8	23	Removable dentures made using 3D printing have some benefits that increase their accuracy and patient comfort.	Prosthodontics
9	24	The prospect for educational development in the crucial pulp treatment and cariology fields is provided by the benefit of integrating new technology in terms of boosting student confidence and decreasing stress.	Endodontics
10	26	With the test guide and the control, implants were inserted precisely for single posterior edentulous spaces. It is necessary to conduct additional research in scenarios with numerous missing teeth that are more complex.	Periodontics and implantology

Table 2. Summarizes the latest research on machine learning and artificial intelligence applications in dentistry [5, 6, 35-45].

S. No	Citation Number	Conclusive Statement	Dental Specialty Domain
1	5	Although dentists have a favourable opinion of robotics and artificial intelligence, there will be a pressing need to raise knowledge of this idea in the near future.	Dental education
2	6	Participants expressed optimism and believed that AI would have a beneficial effect on dentistry practice in the future.	Clinical practice
3	35	Understanding the importance of haptic virtual reality simulators in dental education is made possible thanks to the work, which is a critical first step.	Dental education
4	36	The findings of this study suggest that a skill can be transferred from one level of force feedback (FFB) to another, provided students practice it for a long enough period of time.	Dental education
5	38	When trained on two-dimensional panoramic condyle pictures, the artificial intelligence model enhanced the ability to diagnose TMJ-OA and can be successfully used by dentists as a screening diagnostic tool for the condition.	Diagnosis
6	40	Despite being in its early stages, artificial intelligence is expanding the potential of cutting-edge dental models. To evaluate the clinical effectiveness of AI approaches in dentistry, more research is necessary.	Clinical practice
7	41	A machine learning-based automated system performs quite well. They can even outperform dental specialists in terms of performance and accuracy, mimicking the precision and accuracy of experienced specialists.	Treatment outcome
8	43	AI models have the potential to be an effective tool for detecting the margin of the tooth preparation, forecasting the failure of a restoration, and helping to diagnose caries and vertical tooth fracture.	Diagnosis
9	44	The analysis suggests that artificial intelligence is predominantly employed in dentistry to assess digital diagnostic techniques, notably radiology. However, its utilization is expected to progressively extend across all domains of the profession.	Diagnosis
10	45	Despite being in the developmental stage, AI models designed for implant type recognition, success prediction, and design optimization have displayed significant potential.	Treatment outcome

Table 3. Summarizes the latest research on robotic applications in dentistry [2-5, 46-51].

S. No	Citation Number	Conclusive Statement	Dental Specialty Domain
1	2	The current development in digital human-centered automation, according to the authors, can significantly enhance dentistry and turn it into a new robotic, ML, and AI-enabled era.	Dental Education
2	3	Prediction, diagnosis, and therapy management have all been transformed by artificial intelligence and robotics in contemporary dentistry.	Diagnosis and treatment plan
3	4	The study's findings support a bright future for effective AR and AI integration across a range of robotic applications.	Dental Education
4	5	Growing public knowledge of robotics is crucial going forward because it could improve the effectiveness and efficiency of medical care.	Treatment outcome
5	46	The authors strongly advocate an evidence-based approach for adjusting to new (robot) technologies even though they are optimistic that robots may one day offer valuable solutions.	Clinical practice
6	47	The findings show that participants are generally more eager to have a procedure done if it is half price than if it is full price and that females are less willing to have a robotic dental surgery done.	Clinical practice
7	48	It has been demonstrated that using a full-body patient simulation system helps students develop a more positive attitude towards patients and emphasizes the value of taking real patients into account when providing dental care.	Dental Education
8	49	It is still difficult to do computer-guided flapless zygomatic implant surgery. Planning meticulously and having the surgical guide perfectly stable are crucial.	Treatment outcome
9	50	The use of the surgical robot system for the insertion of the zygomatic implant can increase the precision of the procedure, as shown by a comparison between the robotic and manual operation.	Clinical practice
10	51	The robot might make it easier and more accurate for surgeons to move bones.	Clinical practice

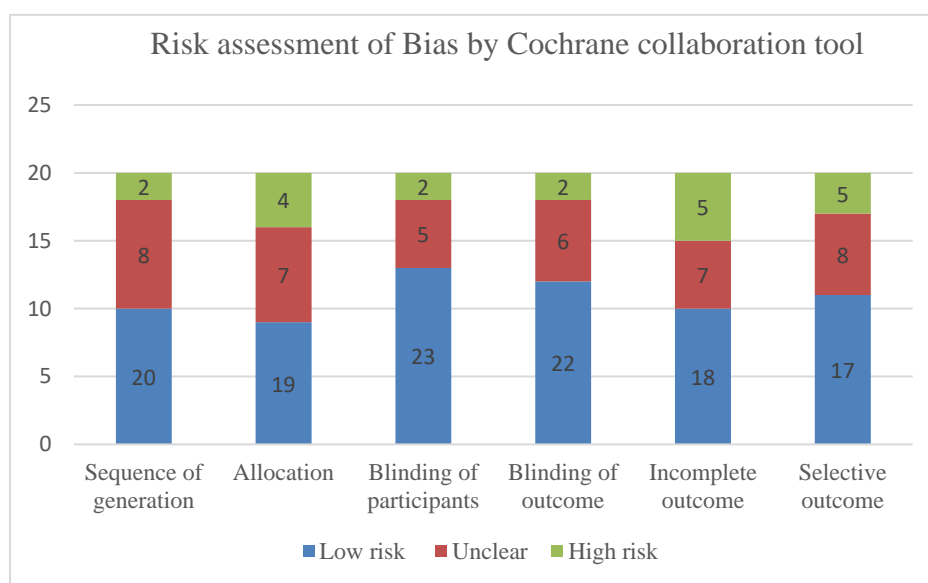


Fig. (2). Assessing bias risk using the cochrane collaboration tool.

Table 4. Evaluation of study quality using the Critical Appraisal Skills Program (CASP) scale for the chosen studies in the systematic review.

CASP Scale	3D Printing Studies (10)	AI and ML Studies (10)	Robotic Studies (10)
Clearly focused question	Y	Y	Y
Appropriate design	Y	Y	Y
Appropriate recruitment	Y	N/D	N/D
Matched control	Y	N	N
Test procedure clearly described	Y	N/D	N/D

(Table 6) contd....

CASP Scale	3D Printing Studies (10)	AI and ML Studies (10)	Robotic Studies (10)
Appropriate outcomes used	Y	Y	Y
Outcome accurately measured	Y	Y	Y
Confounding factors accounted	N/D	N/D	N/D
Appropriate analysis	Y	N	N
Precise statistical results	Y	N	N
Interpretation of evidence	Y	N/D	N/D

Note: Y=yes; N-No; N/D-Not Determined.

Based on the various domains considered in this systematic review, approximately 66.10% of the judgments were classified as low risk, 22.77% as ambiguous, and 11.13% as high risk (Fig. 2).

4. DISCUSSION

In particular, the systematic review identified relevant studies and conclusions about the widespread use of advanced technology, which has become a requirement for greater patient satisfaction levels with diagnosis, treatment plans, and treatment outcomes in the health professional professions of medicine and dentistry [31-34].

It is preferable to recognize and summarize the widespread application of advanced technology in dentistry at various levels of patient management. According to this review conclusion, many dental doctors are quite up-to-date when it comes to promoting innovative technologies in patient care. Every dental clinician and patient receiving dental care will have access to enhanced dental care thanks to the systematic review's assistance in disseminating information about newer technology to larger populations [35-39].

Dental care has greatly benefited from new technology, which has increased its effectiveness, safety, and accessibility [40-43]. In addition, the review intends to address the secondary outcomes with a limited number of additional outcomes. The secondary outcomes are specific to only some comparisons in the review. The secondary outcomes addressed in this review are technological breakthroughs utilizing artificial intelligence, machine learning, and more invasive situations like autonomous implant implantation, which have finally been paired with complicated 3D navigation or tooth preparation processes that have been published in the literature [44-46]. These examples range from digital X-rays to 3D printing. This change paves the way for dentists to provide better patient outcomes and more affordable dental treatment for marginalized communities [47-49].

The perspectives of Gracco A *et al.* (2023) and a systematic review by Bassyouni Z *et al.* (2021) showed evidence to refer to the use of advanced technology in dental practice. The advanced technology aims to provide patients with more effective and efficient treatments; in other words, advanced technology has substantially changed the profession of dentistry.

According to a study by Gracco A *et al.* from 2023, technological advancements have fundamentally transformed the delivery of dental treatment, enhancing precision, safety, and patient comfort. Notable examples

include digital X-rays and 3D printing. This study highlights the overwhelmingly positive impact of new technology on dental care, suggesting that this trend will likely persist in the future from a public health perspective. The findings of the current study indicate that newer, more advanced technologies will influence all aspects of dental patient care [1].

In order to promote dentistry, Grischke J *et al.* (2020) presented the community with innovative inputs and made the case for a greater use of these recent technical advancements, known as Dentronics. The study's findings reveal the application of machine learning (ML) and artificial intelligence (AI) in dental research, employing data-driven analysis algorithms to analyze extensive datasets for aiding in dental diagnosis, prognosis, and treatment planning. These definitive results align with those of Grischke J *et al.* indicating that modern technologies, such as robotics, machine learning, and AI, indeed influence the outcomes of dental treatment [2].

In 2023, Mayta-Tovalino F *et al.* examined the dental uses and perspectives of artificial intelligence, machine learning, and "Dentronics". As per the study authors, the integration of artificial intelligence has transformed prognosis, diagnosis, and treatment management in contemporary dentistry. According to the results of the current comprehensive investigation, artificial intelligence could be used to manage future data in this area [3].

In a cross-sectional observational study, Abouzeid HL *et al.* (2021) gathered information from 570 participants in the Saudi Arabian population. The study assessed dentists' knowledge of how robotics (R) and artificial intelligence (AI) fit into preventive dentistry and oral health. Dentists who participated in the study were dental interns, graduates, and postgraduate dentists. The findings from both studies suggested that although dentists generally held a positive attitude towards robotics and artificial intelligence (R/AI), their utilization and application were hindered by a lack of knowledge and understanding. To enhance treatment efficiency and efficacy in dentistry, raising awareness of these concepts will be imperative in the near future [5].

In order to learn more about Turkish dental students' attitudes towards AI and their beliefs about its potential usage in dentistry, Yüzbaşıoğlu E *et al.*, 2021, evaluated those attitudes and perspectives. Out of the 1103 respondents, 48.40% had at least a basic understanding of artificial intelligence (AI) technology, while 10.6% said they had no sources of information on AI. AI will revolutionize dentistry, according to 85.70% of

respondents, although 28.60% disagreed that it will eventually replace dentists. All of the participants expressed optimism and believed that AI would improve dentistry practice in the future, which is consistent with this systematic review's concluding observations [6].

Di Fiore A *et al.* (2022) investigated the precision of modern intraoral scanners (IOSs) for full-arch digitized implant impressions. The computer programme was created to locate points on each scanned body and perform a 3D position and distance analysis. The study demonstrated that all intraoral scanners (IOSs) could generate a digital full implant impression *in vitro*, based on the average misfit value published in the literature (150 µm). However, 3D distance analysis revealed that only Primescan and iTero had negligible systematic error sources. These are in line with the 3D technology applications listed in this systematic study [8].

5. STRENGTHS AND LIMITATIONS

This systematic review can help us know about advanced technology to be used in dental practice and also provide various applications of advanced technology in dentistry, often to a greater extent than the findings of a single study. This review informs clinicians, students, and patients about the availability of newly advanced technology and its applications in dentistry. Further, the governing bodies must conduct ongoing dental education programs. Moreover, quantitative analysis from multiple studies was not conducted in this systematic review.

6. FUTURE RESEARCH DIRECTIONS

AI and ML are still only used for extremely specialized research questions. More adaptive systems with broader application areas must be defined after their uses at the human level [50-59].

CONCLUSION

In the twenty-first century, technological advances and practices adopted from the e-commerce and tech sectors may help the transition to a sustainable oral healthcare system that offers high-quality, value-based care to a wider variety of patients.

CLINICAL IMPLICATIONS

The governing bodies must conduct continuing dental education programmes to teach practitioners, students, and patients about the availability of newly advanced technology and its applications in dentistry. This shift paves the way for dentists to provide better patient outcomes and more affordable dental care to underserved regions.

AUTHORS' CONTRIBUTIONS

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

LIST OF ABBREVIATIONS

PRISMA	= Preferred Reporting Items for Systematic Review
AI	= Artificial Intelligence
ML	= Machine Learning
PICO	= Population, Intervention, Comparison, Outcome
CASP	= Critical Appraisal Skills Programme
UCLP	= Unilateral Complete Cleft Lip And Palate
MADs	= Maxillary Arch Dimensions
FFB	= Force Feedback

CONSENT FOR PUBLICATION

Not applicable.

STANDARDS OF REPORTING

PRISMA guidelines and methodology were followed.

AVAILABILITY OF DATA AND MATERIAL

All the data and supportive information are provided within the article.

FUNDING

None.

CONFLICT OF INTEREST

Giuseppe Minervini is the Editorial Advisory Board member of The Open Dentistry Journal.

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Declared none.

SUPPLEMENTARY MATERIAL

PRISMA checklist is available as supplementary material on the publisher's website along with the published article.

Supplementary material is available on the publisher's website along with the published article.

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