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*Review*

# Investigation on the Application of Artificial Intelligence in Prosthodontics

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**Abstract:** Artificial intelligence (AI) is a contemporary, information-driven innovative technology. Prosthetic dentistry, also known as prosthodontics, is the restoration and reconstruction of missing teeth utilizing implants for permanent and removable prostheses. It enhances healthy soft and hard tissues, promoting oral health. This study examined the use of artificial intelligence in prosthodontics to diagnose abnormalities and create patient-specific prostheses. Two researchers searched Google Scholar, Scopus, PubMed/MEDLINE, EBSCO host, Science Direct, and Web of Science (MEDLINE, WOS, and KJD). Articles on AI in English were reviewed. We also collected the following broad article aspects: research and control groups, assessment methodology, outcomes, and quality rankings. This methodological study examined AI use in prosthodontics using the latest scientific findings. The findings were statistically evaluated using ANOVA. Titles and abstracts revealed 172 AI-related dentistry studies, which were analyzed in this research. Thirty-eight papers were eliminated. According to the evaluation, AI was found to have significantly increased in prosthodontics. Despite the vast number of studies documenting AI applications, the description of the data illustrated the latest breakthroughs in AI in prosthodontics, highlighting its use in automatically produced diagnostics, predicting analytics, and classification or verification tools.

**Keywords:** artificial intelligence; prosthodontics; ANOVA variance



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## 1. Introduction

Prosthodontics is a branch of dentistry that is considered both an art and a science. It is the art and science of diagnosing, planning, rehabilitating, and preserving the function, comfort, appearance, and health of the oral structures of patients with clinical problems caused by missing or deficient teeth and oral and maxillofacial tissues. It fulfils this purpose mostly by replacing missing teeth and associated structures with artificial ones [1–7]. Prosthodontics focuses on the treatment and construction of removable and fixed dental prostheses, as well as the preparation of finishing margins along the tooth for better extension and fitting of the crowns, implant surgery, and the construction of a maxillofacial prosthesis. It is also used to develop and maintain the relationship between the upper and lower jaws for a stable prosthesis [8–10]. AI can be very helpful in many different kinds of therapy.

Prosthodontics, or the study of dental prostheses, is an important subject that has a broad influence on different phases of a dentist's life. Advancements in digital dentistry

positively influenced prosthodontics and led to exponential development in the field of materials used, diagnosis and treatment planning, and even in prosthesis fabrication. Several factors can contribute to the fabrication of dental prostheses.

First, it was suggested that the deterioration in dental morphology poses a threat to a person's physical, mental, and behavioral health [1,2]. Due to difficulty in biting (or breaking down food), the patient starts shifting the food choices to a softer one or even try to avoid food.

Second, tooth loss makes people more isolated because of concerns regarding social approval [3]. Arguably, having beautiful teeth helps you socialize more since people generally want their entire body to look good. Finally, having a tooth in the oral cavity helps to keep the tongue, lips, and cheeks in the right positions, giving the facial features a proper shape [4]. In prosthodontics, the replacement of missing teeth is possible with the help of implants and crowns [5–10].

Advancements in digital dentistry positively influenced prosthodontics and led to exponential development in the field of materials used, diagnosis and treatment planning, and even in prosthesis fabrication. Several factors can contribute to the fabrication of dental prostheses. When there is a loss of teeth, the construction of prostheses such as removable partial dentures, fixed dental prosthesis or implants provides an alternative [11–13]. The type of implant utilized, and the health of the remaining residual alveolar ridge, determine how rehabilitation can be carried out. Multiple techniques are required during this rehabilitative procedure [14,15].

Artificial intelligence (AI) applications are widely used in digitized daily life [16–19], such as in the form of online companions such as "Alexa" or "Siri", and they are used in many technical disciplines. AI algorithms are widely used in the medical field to analyze images by extracting features and performing target studies [20,21]. Over the past five years, there was an increase in studies on the usefulness and use of AI in radiology to enhance workflow and alleviate some of the radiologist's workload. Although dental technology is improving, it is still behind medical technology [22–31]. In conventional treatment, standardized digital dental methods are used. The desktop design and CAD/CAM fabrication became standard in healthcare and labs. AI application is a new concept that is starting to emerge as dental digitization advances [32]. Dentures for edentulous patients are difficult to create because of the high aesthetic and functional criteria that must be satisfied. The CAD/CAM software's machine learning can realign the teeth to restore the inter-maxillary connections. Artificial intelligence (AI) might help with precise color matching in difficult aesthetic circumstances involving a single central incisor or several front teeth. In implant prosthodontics, implant locations may be identified with the use of intraoral detectors, and this information can then be inputted into the CAD program in real-time. Artificial intelligence (AI) has the capacity to improve dental implant design and fabrication [32].

AI (artificial intelligence) applications are used in many parts of our digital lives [16–19], such as online assistants like "Alexa" and "Siri", and in many technical fields. In the medical field, AI algorithms are often used to analyze images by pulling out features and doing target studies [20,21]. In the past five years, there have been more studies on how AI can be used in radiology to improve workflow and make the radiologist's job easier. Dental technology is getting better, but it is still not as good as medical technology [22–31]. Standardized digital dental methods are used in traditional dental care.

In labs, CAD/CAM fabrication is now the norm. AI application is a new idea that is starting to take shape as digital dentistry gets better [32]. Dentures for people with no teeth are technique sensitive because and they have to meet strict aesthetic and functional standards. Machine learning in the CAD/CAM software can realign the teeth to fabricate complete dentures with accuracy. Artificial intelligence (AI) could help match colours exactly in case of missing central incisors or adjust the colour with remaining natural teeth. In implant prosthodontics, an intraoral detector can be used to find the location of implants. This information can then be put into a CAD program in real-time. AI has the potential to make it easier to design and make better dental implant prosthetics [32].

The present review is novel and very specific to the field of dentistry, specifically prosthetic dentistry. It fills the gap in the literature in a way that there are various reviews pertaining to the use of AI in dentistry, endodontics, and oral medicine, but there is a need to provide a review in prosthetic dentistry which is lacking in the literature. This lacuna is filled by this review, as it explains the use and enhances the value of AI in field of dentistry and, more specifically, to prosthetic dentistry. This review will help in explaining the use and working of AI in different fields of prosthodontics, which would ultimately help the patients and improve satisfaction with the prosthesis.

Humans are increasingly demanding, and always ready for more detailed and thorough medical/dental care; therefore, relying on artificial intelligence can improve the standard of care for patients. AI provides cutting-edge decision-supporting technologies in the discipline of prosthodontics. Therefore, this review aimed to explore and identify the various filed in prosthodontics where AI is used and how it is useful in providing prosthodontic care.

## 2. Methodology

With the advancement in the field of technology, AI plays an important role not only in our day-to-day life but also in the field of dentistry, as well as in enhancing prosthetic rehabilitation. The present review was conducted with the same purpose of exploring and identifying AI use in prosthodontics. This review was filed and registered in the International Database to Register Systematic Reviews (INPLASY) dated 24 December 2022. The DOI registration no. is 10.37766/inplasy 2022.12.0096. It followed the PRISMA 2020 [33,34] and Cochrane criteria [35]. Figure 1 represents the flow chart depicting the methodology used in this review.

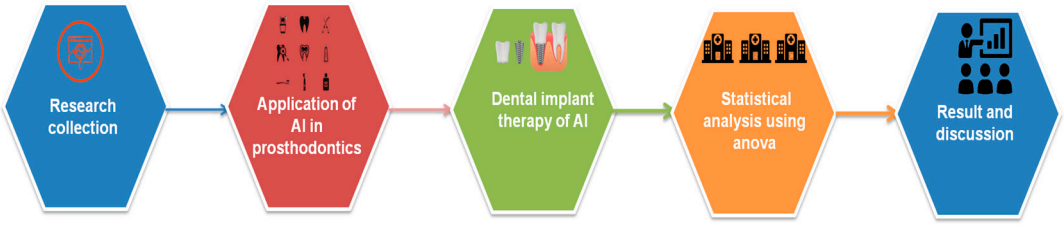


**Figure 1.** The flow of review methodology.

This systematic review followed PRISMA guidelines [33]. For the PICO question, the following statements were formulated:

1. What kinds of AI methods are currently being employed in the prosthodontic field?
2. How does AI enhance clinical decision-making and outcomes in prosthodontics?
3. What are the current clinical uses of AI in prosthodontics, and how well does it work as a diagnostic tool during the determination of the type of prosthesis required for a particular patient?

P—population: images of patients' and simulators' faces in two and three dimensions, as well as a variety of radiographs used during the prosthodontic rehabilitation procedure (including periapical, OPG, and cone-beam computed tomography). I—intervention: machine learning, natural language processing, and robots are used for the diagnosis, management, and prognosis assessment of prosthodontic procedures. C—comparison: image analysis, testing models, and automation algorithms involved in prosthodontic steps while using the digitalized method of prosthetic rehabilitation. O—outcome: several areas of prosthetic dentistry may benefit from the use of artificial intelligence, including performance, accuracy, precision, sensitivity, and clinical decision support (CDS).

Study design: English-language publications of both observational research (such as case–control and cohort studies) and experimental research (such as randomized controlled trials) were included in this analysis, which was basically concerned with the prosthodontic workflow.

### 2.1. Data Collection

Google Scholar, Scopus, PubMed/MEDLINE, Science Direct, EBSCO host, and Web of Science (MEDLINE, WOS, and KJD) provided scientific studies on AI in prosthodontics (WOS, KJD, MEDLINE, RSCI). Only prosthodontic papers were extensively collected. Each category was a mix of MeSH keywords and free-text words (Prosthodontics [Mesh]). The following parameters for inclusion and exclusion were followed: English-language articles, all evidence-based studies except expert opinions, and content from the previous four years (from 2017–18 to 30 September 2021–22). The following descriptions of studies were excluded: case reports with less than ten patients, editorials, reviews with no access to or full text of the document, and research articles on animal models.

Data Extraction

To choose studies and report AI in prosthetic dentistry, several publications were reviewed. The judgment of two review writers (S.C. and R.S.S., both prosthodontists) independently was considered to select and finalize the publications. Two steps were used to do this: first, matching was carried out for the titles and abstracts of all studies according to the inclusion criteria; next, the full texts of the publications that were deemed good from the first round of screening were examined. Information extraction: the two reviewers (L.A. and F.H.) performed their data extraction work independently at first, and then, compared and revised their results. The following information was gathered from different sources: details of the author(s), publication year and nationality, aim of the study, patient records, application of AI, test datasets, and outcome.

### 2.2. Study Selection

Based on the primary search keywords and phrases, 172 articles were identified. A total of 35 duplicates were eliminated, and 90 papers were screened based on their titles and abstracts, of which 21 were excluded. So, 69 reports were sought for retrieval. Eight items that could not be retrieved from the search were excluded. The eligibility of the remaining 61 studies was evaluated. A total of 32 reports were also excluded due to various reasons as described in the flow chart presented in Figure 2. Finally, 24 articles were included and examined. Figure 2 shows the PRISMA flow diagram of the literature review.

### 2.3. Study Characteristics

The studies included in the review were mainly systematic reviews, retrospective studies, and meta-analyses. (Table 1). Most of the research (66%) was published in the previous four years.

**Table 1.** Description of the study characteristic.

| Study Title, Author Name and Publishing Year [Citation] | Country | Study Design | Journal | Aim of the Study |
|---|---|---|---|---|
| Artificial intelligence for fast and accurate 3-dimensional tooth segmentation on cone-beam computed tomography (EzEldeen et al. [36]) | Belgium | CBCT | Journal of Endodontic | The purpose of this research was to create and verify an AI-driven instrument for automatic teeth segmentation using cone beam computed tomography (CBCT). |
| Machine learning and intelligent diagnostics in dental and orofacial pain management (Farook et al. [37]) | Malaysia Saudi Arabia | Systematic review | Pain Research and Management | Machine learning was investigated to determine its clinical impact, efficacy, limitations, and results when compared to human diagnostics for identifying the root causes of dental and orofacial pain, and (6) bone and temporomandibular joint. |

**Table 1.** *Cont.*

| Study Title, Author Name and Publishing Year [Citation] | Country | Study Design | Journal | Aim of the Study |
|---|---|---|---|---|
| Uses of Different Machine Learning Algorithms for Diagnosis of Dental Carie (Talpur et al. [38]) | Pakistan | DDC | Journal of Healthcare Engineering | The primary goal of this research was to systematically examine existing literature on the topic of how machine learning can affect dental caries. The PICO criteria will be used as a framework for this study's design. |
| Outcome measurements and quality of randomized controlled clinical trials of tooth-supported fixed dental prostheses (Limones et al. [39]) | Spain | Systematic review | The Journal of Prosthetic Dentistry | This systematic review aimed to identify all primary and secondary outcome metrics in tooth-supported FDP RCTs. Secondary aims were to assess methodological quality using the Cochrane Collaboration's risk of bias instrument (RoB, v2.0) and reporting quality using a 16-item CONSORT evaluation tool through published reports. |
| Robot technology in dentistry (Van Riet et al. [40]) | Netherlands | Systematic review | Dental Materials | The goal of this evidence-based review was to give dentists and researchers a bird's-seeing view of the features of the literature surrounding dental robotics projects. |
| A risk of bias tool and guideline to support reporting of pre-clinical dental materials research and assessment of systematic reviews (Delgado et al. [41]) | Spain, Brazil, etc. | Systematic review | Journal of Dentistry | The purpose of this study was to aid in the reporting of future investigations and to enhance the assessment in systematic reviews. |
| Artificial Intelligence and Surgical Education: A Systematic Scoping Review of Interventions (Kirubarajan et al. [42]) | Canada | Systematic review | Journal of Surgical Education | The purpose of this literature review was to consolidate the available research on the application of AI to surgical education. |
| Accuracy of intraoral scanners versus traditional impressions: A rapid umbrella review (Afrashtehfar et al. [43]) | Switzerland | RU review | Journal of Evidence-Based Dental Practice | The primary purpose of this research was to (1) evaluate the reporting quality of titles and abstracts of the collected literature and (2) assess the truthfulness and precision of intraoral scanning (IOS) in dentistry based on recent secondary sources. |
| Accuracy of Digital Dental Implants Impression Taking with Intraoral Scanners Compared with Conventional Impression Techniques: A Systematic Review of In Vitro Studies (Albanchez-González [44]) | Spain | Systematic Review | International Journal of Environmental Research and Public Health | This systematic study aimed to assess the in vitro accuracy of dental implant impressions produced with an intraoral scanner to those taken with more traditional methods. |
| Accuracy of removable partial denture metal frameworks fabricated by computer-aided design/computer-aided manufacturing method: A systematic review and meta-analysis (MAI et al. [45]) | Republic of Korea | Systematic Review | Journal of Evidence Based Dental Practice | The purpose of this systematic review and meta-analysis was to evaluate the precision of removable partial denture (RPD) frameworks made with CAD/CAM systems to those made with traditional casting techniques. |
| Communication tools and patient satisfaction: A scoping review (Touati et al. [46]) | Switzerland | Scoping review | Journal of Esthetic and Restorative Dentistry | This exploratory research evaluated aesthetic dentistry communication. Various communication tools can incorporate patients in SDM. Few know how dental communication technology improves patient satisfaction. Medline, Embase, Cochrane, and World Science were searched for patient satisfaction research. |

**Table 1.** *Cont.*

| Study Title, Author Name and Publishing Year [Citation] | Country | Study Design | Journal | Aim of the Study |
|---|---|---|---|---|
| Robotic applications in orthodontics: Changing the face of contemporary clinical care (Adel et al. [47]) | Egypt and India | CFCC | BioMed research international | This review covered eight orthodontic domains: (1) robotic dental assistants; (2) robotics in orthodontic diagnosis and simulation; (3) robotics in patient education, teaching, and training; (4) wire bending and customized appliance robotics; (5) nanorobots/microrobots for tooth movement acceleration and remote monitoring; (6) robotics in maxillofacial surgeries and implant placement; (7) automated aligner production robotics; and (8) TMD rehabilitative robotics. |
| A review of 3D printing in dentistry: Technologies, affecting factors, and applications (Tian et al. [48]) | China and Republic of Korea | Technological application | Scanning | Three-dimensional printing has uses in dentistry, including prosthodontics, oral and maxillofacial surgery, and oral implantology. The 3D printing review is practical and scientific. |
| Economic Evaluations of Preventive Interventions for Dental Caries and Periodontitis: A Systematic Review (Nguyen et al. [49]) | Australia | Systematic Review | Applied Health Economics and Health Policy | For the purpose of providing a critical analysis of the techniques employed in comprehensive economic assessments of preventative therapies for dental caries and periodontitis. |
| Rehabilitation with dental prostheses and its influence on brain activity: A systematic review (Costa et al. [50]) | Brazil | Systematic Review | The Journal of Prosthetic Dentistry | The aim was to determine whether or not oral prosthesis rehabilitation was associated with an increase in regional brain activity. |
| Detection of Caries under Fixed Prosthodontic Restorations Using Cone-beam CT: A Meta-analysis (Sivaramakrishnan et al. [51]) | Bahrain | Meta-analysis | International Journal of Prosthodontics and Restorative Dentistry | This literature review sought to synthesize the data on cone-beam computed tomography's (CBCT) ability to identify caries under fixed restorations. |
| Intraoral scanning devices applied in fixed prosthodontics (Abad-Coronel et al. [52]) | Cuenca | Dentistry | Acta Sci Dent Sci | Intraoral scanning devices applied in fixed prosthodontics (Abad-Coronel et al. [52]). |
| Efficacy of deep convolutional neural network algorithm for the identification and classification of dental implant systems, using panoramic and periapical radiographs: A pilot study (Lee, 2020 [53]) | Republic of Korea | Retrospective Cohort Study | Medicine | The aim of the current study was to evaluate the efficacy of deep CNN algorithm for the identification and classification of dental implant systems. |
| Artificial intelligence in fixed implant prosthodontics: A retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients (Lerner et al., 2020 [54]) | Germany | Retrospective Cohort Study | BMC Oral Health | Purpose of this retrospective clinical study is to present a protocol for the use of AI to fabricate implant-supported monolithic zirconia crowns cemented on customized hybrid abutments, via a full digital workflow. |
| Predicting the debonding of CAD/CAM composite resin crowns with AI (Yamaguchi et al., 2019 [55]) | Japan | Retrospective Cohort Study | J. Dent. Res. | The aim of this study was to assess the validity of deep learning with a CNN method to predict the debonding probability of CAD/CAM composite resins restorations from 2D images captured from 3D STL models of a die scanned by a 3D oral scanner. |
| Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm (Lee et al., 2018 [56]) | Republic of Korea | Retrospective Cohort Study | J. Dent. Res. | The aim of the study was to evaluate the efficacy of deep CNN algorithms for detection and diagnosis of dental caries on periapical radiographs. |

**Table 1.** *Cont.*

| Study Title, Author Name and Publishing Year [Citation] | Country | Study Design | Journal | Aim of the Study |
|---|---|---|---|---|
| Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm (Lee et al., 2018 [57]) | Republic of Korea | Retrospective Cohort Study | Journal of Periodontal Implant | The aim of the current study was to develop a computer-assisted detection system based on a deep CNN algorithm and to evaluate the potential usefulness and accuracy of this system for the diagnosis and prediction of periodontally compromised teeth. |
| Artificial Neural Networks as a powerful numerical tool to classify specific features of a tooth based on 3D scan data (Raith et al., 2017 [58]) | Germany | Retrospective Cohort Study | Comput. Bio. Med. | The hypothesis was that tooth classification algorithms based on ANNs are capable of classifying teeth with sufficient accuracy for potential use in clinical practice in order to improve digital workflow in dental prosthetics. |
| Evaluation of a Novel Computer Color Matching System Based on the Improved BackPropagation Neural Network Model. J. P (Wei et al., 2018 [59]) | China | Retrospective Cohort Study | J. Prosthodont. | [The aim of this study was] to explore the feasibility of a novel computer color-matching system based on the improved back-propagation neural network model by comparing it with the traditional method. |

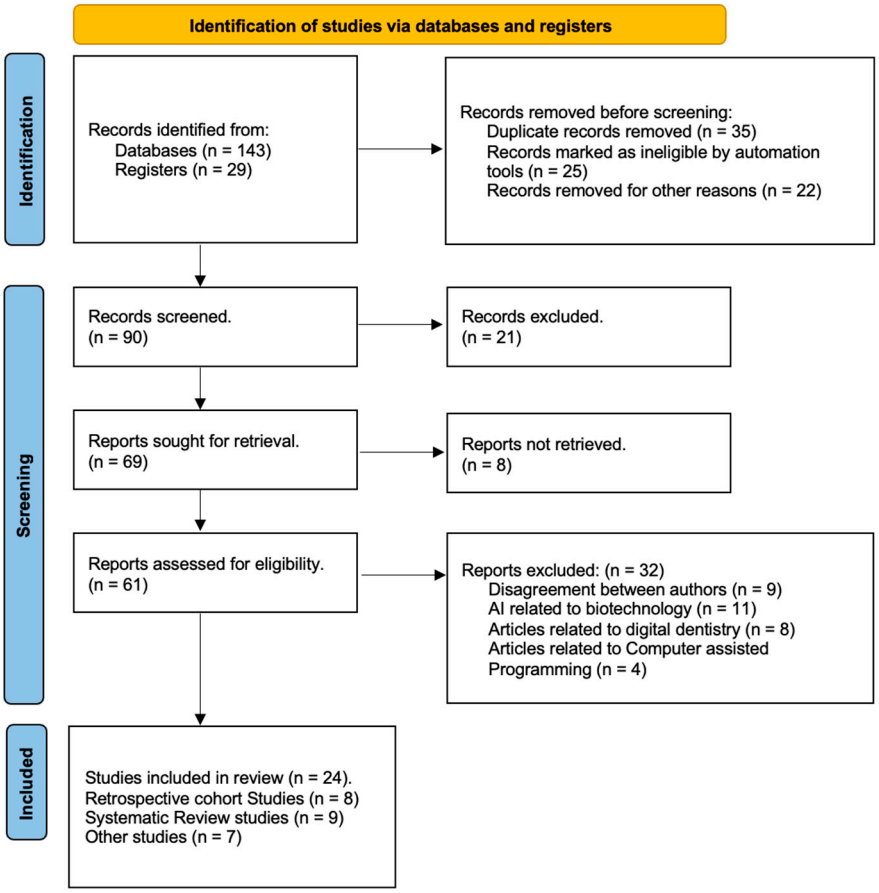


**Figure 2.** Flowchart of the Prisma.

Assessment of the Risk of Bias in Included Studies

The papers that were included had their bias risk evaluated separately by the two researchers. The research was considered to have a low risk of bias if it provided thorough information on 80% or more of the relevant parameters. There was a moderate probability

of bias in studies if the supplied information corresponded to less than 50–70% of the relevant parameters and a high risk of bias if more than 50% of the relevant parameters were left unanswered [60,61].

### *2.4. Statistical Analysis*

Prosthodontics AI research evaluation employed ANOVA [62]. This demonstrates the use of the AI model and its impact on how prosthodontics is impacted, sustained, and upgraded. The standard A-statistic for ANOVA was determined by dividing the sum of the squared averages of the void sample with the anthropocentric principle by the entire model. Each variance was considered equally when determining the parameters using the approach of reducing squared errors.

## 3. Result

### *3.1. Descriptive Analysis*

Eight publications showed various applications of AI within the discipline of prosthodontics, despite their varied origins. Eight studies investigated the development and use of various AI systems [63–71]. Two studies investigated the use of a particular CAD program's built-in AI system for creating prostheses [66]. This review employed a descriptive method to analyze the data supplied by the included research. Table 1 provides a synopsis of the data extraction procedure. Each one of the included studies used a non-randomized, retrospective cohort design. Four of these publications focused on CBCT [64,68,69]. In total, there were four studies that examined neural network models, one that employed a forecasting model, and one that made use of the built-in AI and algorithms of a widely used analytical CAD program. Prosthodontics is a discipline where AI is steadily making inroads and will keep doing so. Development was made in the field, with a focus on CBCT (cone beam computed tomography) and 3D scans for more accurate implant prosthodontic diagnosis. Excellent outcomes were achieved by using AI to precisely create surgical templates and assess bone integrity. This section examines how AI may affect prosthodontics.

### *3.2. Statistical Analysis by ANOVA*

The impact of AI deployment on prosthodontics was examined using ANOVA. The ANOVA test results for the AI application in prosthodontics are shown in Table 2.

**Table 2.** ANOVA test of the AI application on prosthodontics.

| Features | *p*-Value |
|---|---|
| Diagnostic accuracy | 0.022 |
| Error reduction | 0.027 |

All data that could be obtained from the articles were tallied. All papers that met the inclusion criteria were evaluated for potential bias using the quality of evidence scale (Table 3).

**Table 3.** Study bias assessment. (* shows the presence of the factor checked.)

| Stars | Lerner, H.; Mouhyi, J.; Admakin, O.; Mangano, F. [54] | Lee, J.-H.; Jeong, S.-N. [53] | Lee, J.-H.; Kim, D.-H.; Jeong, S.-N.; Choi, S.-H. [56] | Yamaguchi, S.; Lee, C.; Karaer, O.; Ban, S.; Mine, A.; Imazato, S. [55] | Raith, S.; Vogel, E.P.; Anees, N.; Keul, C.; Güth, J.-F.; Edelhoff, D.; Fischer, H. [58] | Lee, J.-H.; Kim, D.-h.; Jeong, S.-N.; Choi, S.-H. [57] | Wei, J.; Peng, M.; Li, Q.; Wang, Y. [59] |
|---|---|---|---|---|---|---|---|
| Determination (Max. 4 Stars) | *** | ** | ** | *** | ** | ** | * |
| Comparison (Max. 2 Stars) | - | - | - | * | - | - | - |
| Outcome (Max. 4 Stars) | * | * | * | * | * | * | * |

### 3.3. Diagnostic Accuracy

All subsequent therapies and suggestions were based on the results of the diagnostic accuracy examination. A thorough evaluation of the patient's teeth, musculature, and associated tissues are required. Challenges with missing teeth, complications with replacement, and arch diagnosis for implant surgery are necessary. AI significantly increases diagnosis accuracy.

The improvement in diagnostic accuracy explains the improvement in diagnosis during prosthodontic rehabilitation and showed that the use of AI was directly proportional to accuracy. Here, diagnosis includes the determination of the problem, the decision on the type of prosthesis, and finalizing the design and related components in removable and fixed prostheses.

AI and machine learning emerged as powerful tools for assisting diagnosis, determination of the type of prosthesis requirement, the development and positioning of clasps in RPD, designing of connectors and pontics, etc. Given this vast amount of data being generated, dentists/prosthodontists today are faced with an overwhelming amount of information when working to rehabilitate even a single patient. AI has the potential to provide these professionals with the ability to speed up and improve their rehabilitative capabilities by helping to extract clinically relevant insights from the wealth of information available. AI technologies are making great strides in medical imaging. Studies showed that the use of AI may be able to enable earlier disease detection, while also enhancing the workflows. AI can review r vast numbers of images and then, quickly and regularly identify patterns, including variations that humans cannot. This may improve patient rehabilitative treatment outcomes. This adds to the huge potential of AI to support clinical decisions in time-critical situations or when there is a lack of expert knowledge available. AI has incredible potential for analysis and diagnosis. Most of the time and effort in a lab is spent on pre- and post-analytical processes. AI could help bring significant improvements to the workflow and operations, saving time, labor, and costs.

### 3.4. Error Reduction

Similarly, error reduction was enhanced with the use of AI in prosthodontics. When using traditional dental methods, there may be several issues when cementing implant prostheses, postural mistakes, directional errors, cementation faults, and occlusal or interproximal errors that might occur. With the use of AI, the possibility of errors was reduced to a minimum and the development of satisfactory functional and aesthetic prostheses was increased.

## 4. Discussion

In this comprehensive assessment of AI technologies utilized in prosthodontics, the predictive power and identification potential of AI for application in automated diagnostics were proven [72–74]. Due to the rapid evolution of digital technologies, in the past 2–3 years, the time frame for this investigation was set to the last four years. This systematic study was not intended to serve as a comprehensive history of AI in dentistry but rather to highlight applications for prosthetic AI. The findings demonstrated that CAD/CAM systems, implant prostheses, and studies of orofacial anatomy were just a few examples of the ways AI was used in prosthodontics. The application of AI in prosthodontics was the subject of only 24 qualifying studies. Although dynamic caries detection was the focus of artificial intelligence dental image analysis diagnosis for some time, the discipline moved to other areas of interest, demonstrating the utilization of AI technology in prosthodontics, and the large and complex field of prosthodontics in dentistry may profit from routine AI technology application [75–77].

For a prosthetic reconstruction to be effective, it must have a synoptic treatment idea, sufficient backward planning, and clean practical execution, including dental laboratory processes. Using prosthetic AI, it was possible to diagnose periodontal deficient premolars and molars with 90% and 95% accuracy, respectively [78–81]. However, because of the

redundancy of the imaging characteristics and the visual field of periapical radiographs, this method cannot distinguish between early lesions or offer a conclusive diagnosis of periodontal disease.

### 4.1. Application of AI in Prosthodontics

Artificial intelligence (AI) uses machine-learning models to simulate human intellect and behavior. This model is based on the statistical analysis of past data and was trained using previously gathered data [82–86]. Digital data are generated at an exponential rate, which helps to train AI systems to produce more precise results. With the introduction of artificial intelligence-based technologies in prosthodontics, fundamental shifts were witnessed in their application to automatic diagnoses, predictive measurements, and classification or diagnostic tools [63]. All aspects of modern dental technology are used in prosthodontics. The digital impression with an intraoral scanner replaced the more traditional methods of impression-making. Intraoral scanners are reliable enough for everyday use, especially when only a single crown or short-span FPD is to be fabricated [64]. However, advancements in the scanning field led to its use in complete denture fabrication and maxillofacial intraoral scans.

In fixed prosthodontics, margin detection was completed using AI following an intraoral scan [65]. CAD/CAM, a common acronym for "computer-aided design/computer-aided manufacturing", is used in the creation of both permanent and removable dental prostheses [34]. An ideal crown design for a variety of circumstances may be provided by this technique using data from many actual crowns.

In recent times, many different areas of dentistry used digital tools to help patients obtain the beautiful new smiles they always wanted. These include 3D face tracking and affordable virtual 3D data hybrids such as fragmented cone beam computed tomography (CBCT), intraoral scans, and face scans. Any therapeutic action that changes a patient's smile is predicated on the virtualization of their anatomy [67]. The initial grin designs were created using simple sheet drawings made from two-dimensional printed pictures of patients [68].

Various applications of AI in prosthetic dentistry and its combination with other branches of dentistry led to a wide variety of innovative opportunities, such as the generation of occlusal morphology in crown contemplation of the opposing teeth, even in cases of wear or fracture, programmed teeth setting for dentures, or automatic framework designs for removable dental prostheses [41]. Ultimately, AI, when used as an educational tool, guides new students, graduates, and even postgraduates. AI also provides the opportunity to support less-experienced undergraduate students in their professional development [42].

### 4.2. Use of AI in Implant Prosthodontics

In the field of prosthodontics, both the patient and doctor need the greatest caliber of prostheses. A faultless result requires much equipment and work; however, it occasionally falls short [69]. A developing and manufacturing unit built into a computer enabled us to develop, grind, or print according to a patient's preferences while simultaneously conserving time and materials [70]. The abundance of information available on dental anatomy is frequently considered when evaluating aesthetics. This was in comparison to using a typical framework [71]. The best treatment strategy for dental implants incorporates both intraoral scanning and CBCT. AI's use of AI in implant dentistry presents the opportunity to merge the two and produce next-generation prosthetics [87]. The treatment of temporary and removable dental prostheses, the design of completing margins next to the teeth for improved longevity and alignment of the prosthesis, implant surgery, creation of maxillofacial prostheses, maintenance of ideal maxillo-mandibular relationships, and selection of teeth color for improved appearance are the primary areas of attention in prosthodontics [88]. AI has several benefits and can be applied to many treatment procedures [89]. In research by Lee J et al. [53], panoramic and periapical radiography were utilized to classify implants using convolutional neural networks (CNNs) based on AI [90,91]. Based on the results

of this study, it can be said that the AI-CNN system is virtually as effective as humans in classifying implant methods [91]. Potential causes of errors include incorrect positioning, poor cementation, occlusion, and interproximal repair. An AI model was proposed by Lerner et al. [54] to lessen the likelihood of these errors. A systematic study was carried out by Takahashi et al. [92] to develop an AI framework that would categorize dental arches and utilize CNN to assist in denture manufacturing. Using computer-based autonomous learning approaches, the training dataset was categorized [93–95]. AI augmented reality reduced dental fear and improved patient satisfaction. AI will improve in organizing appointments, playing patients' favorite music and entertainment, and even in helping them to relax in their surroundings [15].

### 4.3. CAD/CAM and AI

Patients and clinicians anticipate high-quality prostheses in prosthodontics. Perfect output requires a lot of personnel and equipment. Computers have built-in creating and producing units that allow us to design, mill, or print custom medical prostheses for patients. The capacity of AI to evaluate and understand prostheses in the database is a significant advantage, especially when considering that new instances are added to the web on a mass scale. Dental anatomy data were used to assess aesthetics [55,82].

### 4.4. Maxillofacial Prostheses and AI

AI employs convolutional neural networks (CNNs) that mimic human neurons. Twelve patients with vision impairments previously tried the prosthetic eye, which was created in the United States. These AI-powered gadgets can help individuals see without surgery. AI and certain designing tools help dentists build the most beautiful prosthesis for patients, considering anthropological calculations, face dimensions, ethnicity, and patient preference. There are smart reading glasses available for the blind and visually challenged. It is an innovative voice-activated gadget that can be attached to almost any pair of glasses. It is designed primarily to help blind and visually challenged people. It can quickly read text from a book, smartphone screen, or any other surface, identify faces, work more effectively, and help its user lead an independent life [75].

The audio output can be heard using the normal microphones used in mobile phones. Skin tissue engineering is a contemporary medical practice that aims to create bioprinter biomaterial-based synthetic skin grafts. This cutting-edge approach to wound regeneration attempts to create skin replacements that work as bioactive dressings, improving the wound's functionality.

As a result, the primary functions of tissue-engineered skin grafts are to give oxygen, prevent the wound from becoming dehydrated, promote healing, and guard against infections. Artificial skin grafts can serve as temporary wound coverings or as long-term skin replacements. Artificial olfaction played a crucial role in mimicking the human olfactory structure for around 40 years; artificial olfactory systems have captivated scientists. According to research, four chemical sensors with overlapping selection patterns may differ between various odors. The categorization, identification, and recognition of scents are all based on the signal combination pattern that emerges in the ensemble of each receptor. As an example of an artificial olfactory system, the electronic nose model, which mimics the human olfactory detection system utilizing a variety of electronic sensors, was developed [35].

The bionic eye was made in the United States, and a dozen people who had lost their sight tried it. AI is used in these technologies, which can help people see without having to have surgery. With this method, a smart camera on special glasses lets the user read text or recognize faces. An expert observes the data from the camera and turns it into sound. This sound is then sent to the blind person's ears through a wireless earpiece. People who have had limbs cut off may lose the ability to feel in those places. Researchers at the Federal Polytechnic School of Zurich in Zurich, Switzerland, and the California Institute of Technology in Pasadena, CA, USA, made artificial skin that changed this picture. The tissue,

made of a thin, see-through layer of water and pectin, can sense changes in temperature between 5 and 50 °C [19]. Artificial olfaction is important in robotics because it mimics the human olfactory system, which can recognize different smells in a wide range of sectors, such as disease diagnosis, environmental monitoring, public safety issues, the food industry, and agricultural production [22].

### 4.5. Limitations of AI

The impact of artificial intelligence on society is already significant and is expected to grow as technology improves. There is always a chance that a badly spelt symbol in the algorithm may cause a major error in the operation, or that overloaded mechanisms will simply cause the system to crash. Additionally, as prosthodontics is entrusting artificial intelligence technologies with more and more crucial tasks, the results of such failures may have unanticipated and highly unfavourable effects.

There is no agreement among contemporary scholars on how to categorize the outcomes of artificial intelligence's acts and whether they produce harm. There are three key ideas: first, identifying the person who used artificial intelligence responsibly; second, identifying the programmer (software developer), if the error was caused by a mistake or failure; and third, identifying the person who owns the rights to artificial intelligence. Today, artificial intelligence technologies are still not fully understood due to the complexity of their systems, and their ability to learn by themselves and change their behaviour.

The information provided to the AI algorithms is the only way they can learn. However, if the software is given faulty or untrustworthy data, the findings may be biased. As a result, the intelligence or effectiveness of AI is only as good as the data provided.

A machine executes an algorithm, which may or may not be programmed by a person. However, flawed algorithms will provide unfair outcomes. AI is known for learning from massive datasets, finding patterns, and making data-driven judgments. Despite its speed and accuracy, the AI system cannot explain how it reached its conclusions, and there may be substantial initial investment as well as regular maintenance and repair costs associated with this new technology. Keeping up with the ever-changing demands of prosthodontics requires that AI software receives regular updates.

### 4.6. Ethical Considerations with AI

AI development should ensure that these programs do not damage people while retaining the morality of computers [74]. There is great potential for the use of AI in clinical practice to advance healthcare, but this potential comes with serious ethical concerns that need to be addressed. Some of today's most powerful companies in the IT sector think that AI should be used more broadly. However, there are numerous ethical and risk assessment considerations to consider before this becomes a reality. Four fundamental ethical challenges must be solved to maximize AI in healthcare: data privacy, informed permission to use data, safety and transparency, and algorithmic fairness and biases. The use of AI may render us unable to hold anyone liable for any harm caused. Machines will restrict our capacity to assign blame and take responsibility for decisions, and the threat is unclear. Healthcare AI must adapt to a constantly changing environment with frequent interruptions while upholding ethical standards to protect patients [75].

### 4.7. Future Scope

AI is changing everything from space research to dentistry. Biomedical diagnosis, therapy planning, patient recording, and management have several benefits. AI aids physicians and patients in every profession, and in the future, AI will produce a forecast that can be merged with human diagnosis to increase the chances of appropriate diagnostics, leading to a higher rate of correct diagnoses.

Despite the encouraging outcomes, it is still important to validate the generalizability and reliability of the provided AI models using adequate external data acquired from newly enrolled patients or gathered from other dental facilities. One of the long-term goals of

AI research in dentistry is to improve AI models to the point where they can detect early abnormalities that are undetectable to the naked eye. There will be a significant need for AI-enabled algorithms as CAD/CAM technology advances and prosthodontic implant procedures require more accuracy.

At all stages of AI development, including pre-modelling, model creation, and post-modelling, explainability can be taken into account. The majority of the research on AI explainability describes post-modelling explainability and seeks to explain an existing black-box model version [96], even though explaining decisions made by artificial intelligence systems can help provide transparency on how the model arrives at its decision. However, at the level of the dentist and specific prosthodontist, the applications of AI is concerned with prosthesis fabrication, the success of which will be tested and determined only when it is placed in the oral cavity and so, if the explainability of AI is not known to us as a prosthodontist, the ultimate effect will be negligible. Despite this, we accept that if it is known it will be beneficial to both the prosthodontist and patient, then it will be beyond the scope of the present review. It is recommended to involve this aspect of AI in future studies and reviews.

AI will improve the clinical and dental patient experience. To improve patient experience, the system will learn preferences. Improved dental patient experiences will increase appropriate oral health care, enhancing systemic health. The software will offer RPD designs for partial edentulism. Research-based, clinically proven technologies and approaches will modernize dental implant therapy. The software will assist with partial denture design in cases of incomplete edentulism. Dental implant therapy can become standardized via the use of tried-and-true technology and procedures backed by years of scientific study.

## 5. Conclusions

It can be concluded that the use of AI is increasing in prosthodontics and its use is enhancing the prosthodontic-driven rehabilitation of patients. AI is helpful in removable, fixed, maxillofacial, and implant prosthodontics. The functionality and acceptance of prosthodontic treatment are enhanced with the use of AI and chances of human error are reduced. It was also revealed that prosthodontic implant applications benefit the most from artificial intelligence. In addition, researchers were found to use AI to create systems for dentistry and overall health.

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