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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman** (**Кириллица**), ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

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UTILIZATION OF ARTIFICIAL INTELLIGENCE FOR PREDICTIVE MODELING IN DENTAL IMPLANTOLOGY

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Abstract.

Artificial intelligence (AI) is making waves in dentistry, with applications in predicting dental implant success. AI models analyze patient data (X-rays, medical history) to identify factors influencing implant viability. The aim is to identify existing research on the use of AI-based predictive models in dental implants.

The following databases were searched: Web of Science, Scopus, Google Scholar, PubMed, and Cochrane Library, using the keywords "Artificial Intelligence," "Dentistry," "Implant," and "Success." The studies were reviewed qualitatively, as quantitative analysis was not feasible due to the lack of specific outcomes and the insufficient number of studies for comparison.

Technology has presented dental implantology with many opportunities, and it is through artificial intelligence that it is advancing. AI is being applied to detect potential implant failure patients, prognosis osseointegration, improve implant design, and master planning and also for data analysis to predict early complications.

Decision trees, random forests, Artificial Neural Networks (ANN), and Deep Learning (DL) improve diagnostics and treatment planning and introduce a powerful predictive model for a successful implant.

Key words. Artificial intelligence, dentistry, implant, success, deep learning, artificial neural networks, predictive modeling, data analysis.

Introduction.

Dental implants are one of the latest technologies in today's dentistry practice which presents here as a more permanent and effective way of replacing teeth compared to conventional methods such as dentures and bridges [1]. They include functionality, aesthetic qualities under dental treatments, and overall hygiene of the oral cavity. The roots of dental implants can be traced back to thousand years BC when few civilized societies practiced tooth restoration through dental implants [2,3]. In the modern era, the introduction of dental implants was pioneered during mid-20th century when a Swedish orthopedic surgeon named Per-Ingvar Brånemark began his research in this field [4]. A dental implant typically comprises three main components: Fixture: an implant fixture considered biocompatible such as titanium or zirconia; Abutment: a connector between the fixture and the prosthetic crown; Prosthetic crown: the final piece that give the look and function of a natural tooth. The implant fixture is fitted in the jaw which forms a secure connection with the natural bone of the patient in 3-4 months of implanting. The abutment is then fixed to the fixture, and the prosthetic crown is made to mimic the look of the regular teeth. It is essential to categorize dental implants according to configuration, position, and usage; the common type of dental implant is endosteal, which is directly fixed to the bone of the jaw in the forms of screws as well as cylinders among others. Subperiosteal implants placed beneath the mucosa but on top of the implants are more appropriate for those patients with little bone foundation [4,5].

Fortunately, one can consider the field of artificial intelligence (AI) as a promising area for enhancement of the implant success rate prediction. When applied to extensive data sets, AI methodologies allow for the accurate recognition of multiple factors that may affect implant outcomes [6,7]. It has the potential to transform the approach of the dentists towards the implants which will in turn enhance patient care eventually. The following review seeks to identify existing research on the use of AI-based predictive models in dental implants. and it discusses the various kinds of data adopted, the various AI techniques utilized, and the effectiveness of these models in estimating implant outcomes. We will also review the possible advantages and disadvantages of applying AI technology in this aspect; and point out the future trends and possible implications to the practice of implant dentistry.

Research Problem.

Despite years of previous findings related to different aspects that affect implant success, conventional approaches to prediction are insufficient in modelling the relationships between these variables. AI provides higher accuracy and individualised customer solutions, yet poses questions regarding data relevance, compatibility issues and ethical issues.

Research focus.

Introducing artificial neural networks, convolutional neural networks, recurrent neural networks, regression algorithms, support vector regression, and NLP for dental implantology. Examining the data and decision-making process for computing patients' specific characteristics and developing patient-specific risk profiles.

Objectives.

This study will seek to determine the potential of AI to assist in the estimation of implant success, as well as augment pre-surgical planning and such important intraoperative choices as the determination of implant position based on estimated success probabilities and the post-implant monitoring.

Research Question.

How effective are various artificial intelligence (AI) techniques in predicting the success and longevity of dental implants based on patient-specific factors and clinical data?

Advanced deep learning methodologies such as convolutional neural networks (CNNs) demonstrate higher accuracy in classifying the success of dental implants based on detailed CBCT imaging data. AI models are considered reliable when trained with diverse and high-quality data. The random forest model, which combines multiple decision trees, is typically more reliable than a single decision tree because it is less prone to overfitting. However, there are several limitations associated with their use. Artificial neural networks (ANNs) and deep learning (DL), despite their substantial predictive capabilities, require a large amount of data, are computationally intensive, and can be challenging to implement in clinical practice. In contrast, decision trees and random forests, though slightly less precise, are quicker and simpler to deploy.

Literature Review.

Applications of AI in Dentistry:

Diagnostic Tools: It is widely apparent that the incorporation of AI in healthcare leads to improved diagnostic capabilities, planning, and prognostication in a variety of fields, including dentistry. Apps like machine learning (ML), deep learning (DL), and neural networks (NN) as tools have development capabilities that can revolutionise dental practice. More often, technological solutions like AI-based diagnostic tools are being implemented in dental practices. They make use of big patient data and complex computations algorithms in order to enhance the efficiency and preciseness of dental diagnoses. The performance of images based on radiography is one of the main uses that AI applies in its diagnosis. Using traditional methods on the other hand can be so time-consuming and also have chances of interposing errors. These visuals can be analyzed with such a level of detail using AI, especially the convolutional neural networks (CNNs) to diagnose various diseases including cavities, periodontal disease, and even precursors of oral cancer [8,9]. For example, diagnosing caries, with the help of patterns that are invisible to the human eye irrespective of the dental radiographs. The research also recommends that automatically extracted features can perform as well as or better than human operators in differentiating between caries and non-caries as well as distinguishing between healthy teeth and teeth with other pathoses. AI can also help in the identification of oral cancer by examining the relevant images as well as patient data in order to detect possible cases and treat them accordingly at an earlier stage [10-12].

Another important area of its application is diagnostics in orthopedics, here the possibilities of artificial intelligence are huge. Software applications based on AI capabilities facilitate analyses of cephalometric radiographs and 3D scans that can help diagnose having skeletal and dental issues related to malocclusion and other orthodontic problems. Besides improving the diagnostic outcome, this also cuts short the time spent in the analysis of the same, thereby availing the orthodontists more time with the patients [13,14].

Predictions of Implant Success Using of AI.

Image Analysis and Treatment Planning: CBCT scans and intraoral images are used for accessing the quality and quantity of bone tissue, identification of specific anatomical structures, detection of the most suitable implantation zones. thus, enabling treatment planning and also helping to minimize postoperative complications such as implant failure by mimicking implants and assessing bone density respectively [15,16].

AI models determine the chances of implant success by analyzing patient attributes, systematic diseases, smoking status and oral hygiene. In enabling the identification of risk factors that contribute to implant failure, AI supports the decisions of clinicians as well as the effectiveness of the treatment provided [17]. The use of the smart monitoring system during implant placement enables patient- specific monitoring of implant stability and osseointegration over the time. Here it is demonstrated how AI increases long-term implant success and patient satisfaction by indicating signs of complications, such as peri-implantitis, or implant mobility [18,19].

Treatment Planning.

Another vital application of artificial intelligence in dentistry is also in helping to improve treatment planning. Individualized treatment management is critical in enhancing the effectiveness of dental care treatments and applying AI will be valuable in developing such personalized particular management process [20,21]. Using patient's electronic health information, such as patient history, genetic profile and Imaging data AI will help dentists to devise individual interventions [22,23]. In restorative dentistry, AI may assist in identifying ideal prosthetic abutment sites or support surfaces, dental crown and bridge design, and indirect denture framework design. Automating prosthetic using the CAD/CAM system connected with AI facilitates production of proficient models for prosthetic devices leading to proper fitting and enhanced functionality [24,25]. Modern algorithms can evaluate the patient's dental condition and approximate the impact of all possible treatments on it; that is why, dentists can choose the most appropriate treatment strategy. There are many therapeutic specializations in the dental field, and one of the most impacted by AI's contribution to treatment planning is orthodontics. Machine learning can be used to compute for tooth positions and the effects of orthodontic interventions including brace and clear aligner treatment plans. These models allow the orthodontists to predict the likely gains which would occur after executing the treatments to come up with the best decisions on the right treatments to administer. For instance, AI may provide insights into how teeth will shift over time in reaction to orthodontic forces; ways by which treatment plans could be designed to cover minimal time and make the patient as comfortable as possible [26,27].

In implantology, artificial intelligence will play a big role in helping in planning of dental implants. Another advantage that applies AI techniques is the ability to determine ideal implant locations using 3D images of the jawbone, with all important criteria considered, including density and shapes. This precision minimizes the chances of a certain number of complications and enhances the generality of success rates of implant surgeries.

Predictive Modeling.

One of the most beneficial uses of AI is promoting predictive modelling in dental practices. It involves applying AI algorithms to make predictions about the effects of different dental care actions. Specifically, rich patient databases containing demographics and clinical data as well as treatment histories can be analyzed to find out success factors in a particular treatment method and possible complicating factors [28].

In dentistry, one of the key circumstances, that can be identified and analyzed by application of predictive modelling, is the prognosis of dental implants. The success of dental implants has been reported to have several factors that include the health of the patient, the bone quality, and the manner in which the surgery is done. These aspects can be assessed by AI to differentiate probabilities of success or failure rates of implants to guide dental practitioners regarding the most appropriate treatments [29]. For instance, using machine learning, one can use the patient data to determine chances of peri-implantitis or other issues arising from implantation. Such information can assist dentists in identifying and recommending the right candidates for implant operations and adopting various measures that can boost the efficacy of the measures [30].

In orthodontics, in particular, it is useful when it comes to establishing prognoses since it may predict the consequences of various therapies. Another benefit of using artificial intelligence at some point in a patient's treatment is that AI has capabilities of analyzing past patients and outcomes to determine how a specific patient's teeth are likely to respond to certain treatments. Through this capability, orthodontists are able to decide on the right tactics to use in order to successfully treat their patients and to manage their patients' expectations according to the length of time as well as the results that are achievable. Deductive models in periodontics include the application of the AI system to diagnose and determine the likelihood of periodontal disease progression [31]. By identifying patterns in data on the patient's oral health practices, ancestry, and clinical data, the AI can screen which individuals are at a potentially higher risk of developing severe periodontal diseases. Such data assist dentists in putting into practice specific preventive measures and early detection procedures that, if put into practice, may help in lessening the frequency and aggressiveness of periodontal diseases.

AI techniques employed in predictive modelling for dental implant success.

This section explores some of the most common AI techniques employed in predictive modelling for dental implant success, highlighting their strengths and limitations (Table 1). Decision trees are an essential form of ML technique that is very popular due to its feature of being very easy to interpret and works effectively with different data types of data. They function in a manner where every node is an individual decision-making process corresponding to one feature of the data. This next model then goes through the tree decision by decision to the next node depending on the data point of an input until the output is reached which is a predicted class represented by the leaf node [32]. A tree structure can effectively represent the flow of decisions and the various factors that influence predictions, making it easier to understand compared to other structures. For example, data used can include population and patient demographics, medical history, and radiographic data, all of which the decision tree can process adequately. By analyzing the decision path, it is possible to identify the variables that drive the prediction process and focus on a specific set of activities. Decision trees have an induction mechanism that is very sensitive to the training data and may not generalize well from the training data to unseen data. This sensitivity can lead to reduced accuracy in complex scenarios. Decision trees might not perfectly capture all the intricacies of highly complex situations involving several interdependent variables, which can slightly affect the accuracy of the results in such cases.

Decision trees might not perfectly capture all the intricacies of a highly complex situation involving several interdependent variables for input, and therefore the accuracy of the result might be slightly affected in such cases. Random forests are an advanced technique of using decision trees where multiple decision trees are formed at random to enhance accuracy and reliability. Every tree in the forest is learned on a randomized portion of the data and with fewer features at random. The last stage is the formation of the forecast by combining all the forecasts from the trees, and this results in a more accurate model that does not overfit the original decision trees [33]. Random forests improve accuracy significantly. They are

Table 1. *Shows AI techniques employed in predictive modelling for dental implant success.*

AI Technique	Description	Advantages	Limitations
Decision Trees	A simple and interpretable ML technique where each node represents a decision based on one feature, leading to a predicted outcome at the leaf node.	- Easy to understand and interpret - Handles both categorical and numerical data - Can identify important features	- Prone to overfitting - Limited accuracy in complex scenarios
Random Forests	An ensemble method that builds multiple decision trees on random subsets of data and combines their outputs to improve accuracy and reduce overfitting.	- Improved accuracy - Reduced overfitting - Handles missing data	- Black box nature - Computational cost
Artificial Neural Networks (ANNs)	Advanced learning algorithms inspired by the human brain, consisting of interconnected nodes (neurons) that process inputs, learn patterns, and output predictions.	- High accuracy - Ability to learn non-linear relationships - Can handle large datasets	- Black box nature - Requires large datasets - Computational cost
Deep Learning	A subset of ML involving deep neural networks (DNNs) with multiple hidden layers, capable of learning complex patterns and high-level data representations.	- State-of-the-art accuracy - Ability to learn complex features - Does not require feature engineering	- Requires even larger datasets - Increased computational cost - Black box nature

similar to decision trees but use several different trees to enhance decision-making, especially in complicated cases. They reduce overfitting because the random process of constructing training examples prevents overfitting to training data and enhances the ability to generalize to new, unknown data. Random forests also handle missing data effectively. They do not impose restraints on missing data points, as missing data points are managed using the information gathered from other trees in the same ensemble. Although the decision type for each tree is understandable, the textual outcome of multiple trees poses a problem as it is challenging to decipher the meaning of the overall tree. The training and application of random forest algorithms may also be time-consuming due to factors such as the size of the data set.

Artificial Neural Networks (ANNs).

Artificial Neural Networks (ANNs) are a class of advanced learning algorithms whose structure and function clearly reminisce about the human brain. They are composed of numerous nodes (neurons), where each node receives signals as inputs from other nodes, calculates a simple function, and sends the result as output to other layers of nodes. This process enables ANNs to learn and perform modifications based on various aspects of data [34]. The structure of ANNs ensures that they can accurately predict results in systems marked by a high level of interdependency, making them suitable for predicting the success of dental implants. While linear models are limited, ANNs can map non-linear relationships of any degree of complexity due to the nature and architecture of the network. Machine learning enables ANNs to process large volumes of data at a time, thereby yielding a strong capacity for processing extensive datasets in dental implant studies.

Like other methods, such as random forests, ANNs have some limitations, especially regarding the interpretation of internal structures and the interconnections between neurons. In many cases, learning effective ANNs might take some time and require substantial data, which can sometimes be lacking in the field of dental implantology. A disadvantage of training and using ANNs is that it can be a time-consuming, all-encompassing process that must be performed with the use of additional equipment and software.

Deep Learning.

Deep learning is a branch of ML that employs artificial neural networks containing one or several hidden layers which are termed Deep Neural Networks (DNN). Such networks can learn factorial representations, which means that they can model high-level structures of data and capture patterns and dependencies that other models cannot account for [35]. Convolutional Neural Networks and Recurrent Neural Networks have seen considerable leeway for applications in image recognition and natural language processing. This potential renders this method capable of yielding better results for forecasting the success of dental implantations.

Unlike other machine learning algorithms, deep learning algorithms do not require feature engineering; the models learn the features from scratch, which is less computationally expensive and less likely to involve human bias. The problems, which are even larger than typical ANNs, are common issues in training deep learning models and may present a challenge in dental implant studies. Training and using deep learning models are computationally intensive tasks that include constraints on specific hardware and software, which is still hard for less developed research teams. It is similar to ANNs and other deep learning systems where it can be difficult to understand the workings and calculations made by the network (Figure 1).

Comparative Analysis of AI Techniques in Predictive Modeling for Dental Implant Success.

It is also important to compare various AI techniques like decision trees, random forest, ANN and DL, and it was found that each of these models has own paradigm of performances related to accuracy, reliability and computational time. Decision trees are somewhat intuitive and can be applied to different types of data but suffer from high risk of overfitting and certain levels of complexity. Random forests are capable of enhancing the accuracy and decreasing overfitting by utilizing a set of trees, which can be time-consuming and not as easy to understand as decision trees. ANNs have high precision and are useful in predicting patterns with non-linear characteristics, which is relevant to dental implant success. However, they demand massive data and lots of processing power. ANNs with deep

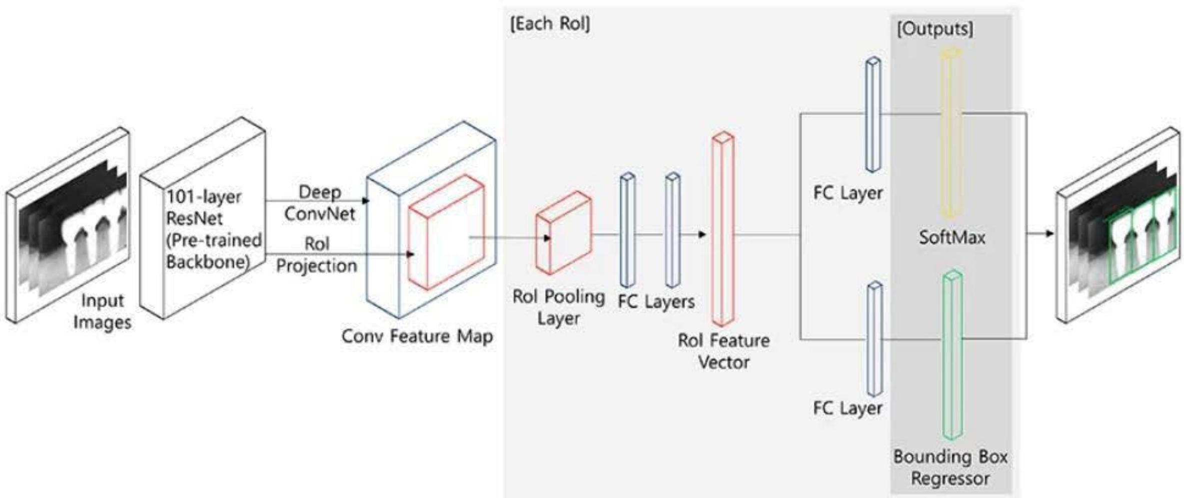

Figure 1. *Dental implant success detection using faster R-CNN [36].*

learning structures are particularly adept at processing facetted features and deliver the best accuracy especially in image recognition. However, DL models require even more data and computational resources, and understanding them is challenging due to their black-box attribute. Therefore, despite ANNs and DL, possessing high accuracy as compared to decision trees and random forests, their use consumes more computational resources [36,37]. Another meta-analysis focused on the efficiency of applying AI algorithms in dental implant planning and more specifically, in identifying edentulous areas and measuring bone thickness.

A total of 12 papers were included in the review, which used cone beam computed tomography (CBCT) images for implant planning employing AI application. This study of both series of data taken together revealed accuracy of 96% in positioning of mandible and 83% in maxilla. Out of all the studies, eight were classified as having a low risk of bias; two studies were classified as having some concerns for risk of bias; and the remaining two studies constituted high risk of bias. The study outcome shows that deep learning-based AI models have high success in segmenting edentulous zones and estimating the bone volume for dental implants using CBCT images. Nevertheless, to enhance the reliability of the findings using the identified design frameworks, it is necessary to perform more extensive studies that would have higher external validity and transferability [38].

Applications of AI in Dental Implant Success Prediction.

This section explores the diverse applications of AI in predicting the success of dental implant procedures.

Identifying Risk Factors for Implant Failure.

There is no doubt that the use of artificial intelligence technologies holds a lot of promise for implant dentistry, particularly for the early identification of patients who are at high risk of implant failure. Patient information such as demographics, medical conditions, X-rays, and surgery characteristics actively fed into an AI model can reveal relationships and correlations that may be hidden from doctors. The information so obtained can be utilized for developing customized care strategies, and using various preventive interventions, and enhancing the general prognosis [35]. AI research shows that this approach can help in the detection of the various other significant predictors of implant failure. For example, Zhang et al. [35] found that the deep learning model utilized features from periapical and panoramic images to accurately forecast implant failures, potentially aiding in early clinical interventions for possible dental implant issues. In the potentiality of becoming a risk assessment model that includes both clinical and radiographic data, the model took into consideration both the clinical assessment and x-ray report as a foundation to analyze the given case study's outcome claim [39,40].

Predicting the Likelihood of Osseointegration.

Thus, osseointegration is an important factor for the long-term stability of the implant since the implant must bond directly with the bone. Currently, to evaluate osseointegration two common methods are used clinically, by analysis and x-rays which may be subjective and have some drawbacks. AI provides a much more feasible solution in estimating the degree of osseointegration with the help of multiple factors of sample data [41].

Research Methodology.

This is a methodologically conducted narrative review to evaluate the implementation of artificial intelligence (AI) in predictive modelling for dental implant osseointegration. The review presents an analysis of the current literature on this subject, discussing some of the most important outcomes, methods and conclusions.

General Background.

The first section briefly outlines the setting of the work focusing on the use of dental implants in the contemporary practice of dentistry and on the possibility to apply artificial intelligence to improve the prognosis models of implant outcomes. It responds to the issues that are usually encountered when using the conventional methods of assessing the outcomes of implantation and emerging approaches [42].

Research Design.

Following a systematic review method, the present review aims at presenting the literature concerning the use of AI in dental implantology. Specific methodological features include the priority of the methods for predicting the outcomes of such implants and measuring their success.

Participants.

The subjects of this review are the scholarly articles recorded in peer-reviewed nine journals focusing on the application of AI in predicting success of dental implants. The former refers to the studies that focus on the performance of AI algorithms in terms of accuracy, reliability and their clinical usability in implant planning and prognosis.

Interventions/Variables.

Specifically, the present review concerns AI-based diagnostic tools as well as predictive modeling methods applied in the context of dental implant planning. Such variables include patient's attributes, imaging techniques and AI models as well as results concerning implant survival rates.

Selection Criteria.

The articles chosen for the review must satisfy certain conditions, such as the focus on the topic, the source in scientific journals, and the possibility of accessing full texts. Some of the reasons for exclusion may be non-peer-reviewed materials, articles in languages other than English, and articles with inadequate data and/or unclear methodology.

Data Collection.

Techniques of data collection include online database search by identifying key databases including but not limited to SCOPUS, Google Scholar and Research Gate. The search is done for articles which were published within a given period of time, time which usually ranges from when the various databases were created up to the current time. The search terms and keywords combined Boolean operators (AND, OR) for optimal results and included "Artificial Intelligence," "AI," "Machine Learning," "ML," "Deep Learning," "DL," "Neural Networks," "NN," "Predictive Modeling," "Predictive Models," "Dental Implants," "Implant Dentistry," "Implant Success," "Implant Failure," "Cone Beam Computed Tomography," "CBCT," "Oral Health," "Dental Radiographs," and "Dental Imaging."

Tools and Procedures.

The systematic approach of the review means that the records are identified using a set of search terms in the databases and the inclusion criteria and exclusion criteria are applied. Contents involve the essential information of the study like objectives of the study, methodology to be used, number of participants, AI techniques used, and results. Data analysis encompasses the process of sorting, integrating, and synthesizing data, making classifications and researching connections and relationships.

Data Analysis.

Data analysis techniques include qualitative integration where studies are grouped according to their methodologies and findings; cross-study summative integration where results are generalized across different studies; and prediction algorithms where regression models that can predict outcomes for subsequent studies are developed. It is possible to use the statistical measures to determine the extent to which the AI models in question are accurate in their outcomes and dependable.

Comparative and Prospective Analysis.

Such criteria for the comparative analysis are the ability to compare the performance of various AI techniques: precision, dependability, and computational complexity. Future studies entail the assessment of the continued advancement and future developments in AI applications specifically for dental implantology.

Ethical Considerations.

Since this is a review of literature, there is no sampling, data collection, or intent to alter the current practices; therefore, the issue of ethical approvals does not arise in this work. Sources are cited to avoid information leakage and strict adherence to legal provision on copyright.

Limitations.

Limitations and biases of the selected studies can be another limitation, such that the compared methodologies may differ significantly across the examined studies, and inherent limitations in AI algorithms may also be present. Ways through which these limitations can be addressed include conducting sensitivity analyses, carrying out subgroup analyses, and conducting studies to validate the results.

Results.

A systematic search employing a specific search strategy yielded 500 articles initially. Subsequent screening based on titles and abstracts narrowed down the selection to 100 articles for full-text evaluation. Upon thorough assessment, 30 articles were deemed relevant and subsequently utilized to inform and construct this review. (Figures 2 and 3).

Various researches have highlighted AI's significant impact on the health field including diagnosis of diseases and correct treatment recommendations. Thus, in dentistry, there is always the need to create new ways of enhancing the quality of a patient's care and the speed of service delivery. AI can improve dentistry through innovations such as early diagnosis and estimating the requirements for dental implants. Alharbi et al [33] aim to develop four new machine learning algorithms: Bayesian network, random forest, AdaBoost, and the new improved AdaBoost algorithms to predict the potential time a patient will need dental implants. This paper shows that the proposed algorithms can accurately predict the likelihood of patients requiring dental implants, guidelines that are useful to managers and administrators in the identification of patients with specific diagnoses. The above analysis suggests that all the developed machine learning models are effective with the enhanced AdaBoost model giving a prediction accuracy of 91.7% this was higher than the other methods by a large margin. This shows that the improved AdaBoost algorithm yields higher prediction ability; this could revolutionize predictive modelling in dental implantology. Another study [28] seeks to explore the possibility of predicting the likelihood of dental implant loss through the application of DL algorithms with the aid of preoperative CBCT images. 279 high-risk patients lost an implant within five years, and 324 low-risk patients who did not lose an implant in total, 603 patients who had implant surgery between January 2012 and January 2020 are selected in this study. Three predictive models were developed: A logistic regression CM based on clinical features; A DL model based on radiographic features; and an integrated model comprising both, the CM and the DL model. The ability of the models was evaluated using the area under the receiver operating characteristic curve (AUC). This study also evaluated the time to implant loss between the two groups, and Ma-titude of Kaplan-Meier curves with log-rank examination. When comparing the measures of performance across the three models, the IM yielded the highest value for AUC of 0.90 (95% CI 0.84-0.95), while the DL model had the next best AUC of 0.87 (95% CI 0.80-0.92). Therefore, it is concluded that the DL model and the integrated model could predict the dental implant loss within five years equally well and offer clinical benefits for implant dentists to evaluate the preoperative risks. Implant dentistry was greatly improved with AI technologies. Altalhi et al [6] focuses on the use of the AI in implant dentistry and shows its advantages in diagnosis, treatment and prognosis variables concerning patient status. The

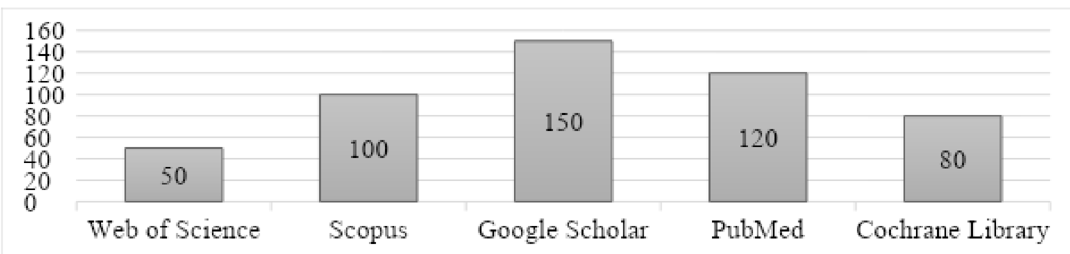

Figure 2. *Distribution of Articles Identified in Different Databases.*

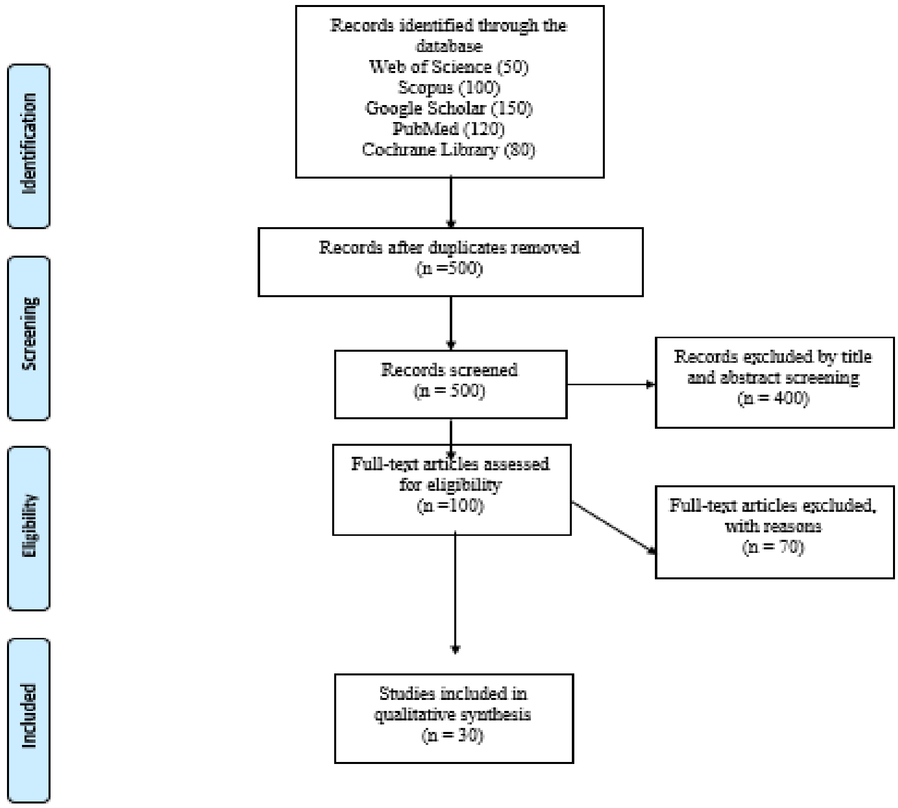

Figure 3. *PRISMA flow diagram of our literature search.*

use of Artificial Intelligence image analysis in combination with deep learning algorithms enhance the accuracy of the implant placement, reduce the risk factors inherent of the operation, and also enhance the aesthetic look of the person. Furthermore, data analytics through AI augments outcomes while dictating specific treatment plans based on each patient, leading to improved success rates. Recently, Effective implementation of implant dentistry which constitutes an integral part of future oral healthcare is expected due to the development of artificial intelligence.

Discussion.

This review aims to discuss the role of AI in dental implantology with a focus on predictive modelling for implant success rates. AI, specifically ML and DL improve diagnosis, treatment, and prognosis in dental practice. AI enhances the accuracy of early diagnosis of dental implant failure and the determination of its success rate through analyzing patient information and radiologic images. AI-based diagnostic tools for dental diseases such as caries and periodontitis are more effective than non-AI methods. In treatment planning, it helps to develop an individual treatment plan and place implants in the best possible way. Machine learning techniques are used to analyze the likelihood of implant failure and estimate treatment prognosis. The review emphasizes the analysis of multiple machine-learning methods for screening dental implant requirements and outcomes. One of the studies reviewed revealed that an integrated clinical feature and DL model produced the highest accuracy. In the modern world, technology especially in the application of artificial intelligence is set to transform dental practice with better patient care as well as efficient oral health care.

There is quite a scarcity in the literature on this topic with only one or two articles and minimal or in some cases no follow-up. Unfortunately, only two randomised clinical trials were identified on the prediction of treatment outcomes in implantology, and no systematic review, meta-analysis or comparative study has been published. The statistical factors of the patients, as described in the research by Lyakhov et al. [34], were used to develop a neural network model to predict survival rates of single dental implants. From the case histories as well as the clinical condition of the patient, the outline of their database was created. Their model observed a high success percentage of 94 %. With single implant survival, the success rate was 48%. They, however, said that this model cannot stand alone or be used exclusively for decision-making, but it can be of great use to the clinician as a diagnostic tool when it comes to implantology.

In their study, Oh et al. found that AI outcomes with plain radiographs can predict the osteointegration of dental implants to some degree and can enhance other ways osseointegration determination methods [43]. In the previous section, seven different DL models made comparisons of two sets of implants: One set was immediately placed while the others were only radiographed after osteointegration. Cha et al have employed an ML approach as a tool to assess the degree of peri implant bone loss from the images from periapical radiography [44]. Still, as they presupposed that the model might help clinicians in the diagnosis and classification of peri-implantitis they failed to establish statistically significant differences between the current bone loss level assessed by the dentists and the AI model.

There are documented articles in the literature that have done the prediction of implant loss using neural networks. Huang et al. have suggested that by using the predictive model being developed by AI it is possible to predict the implant fate within the next five years as this will help dentists recognize high-risk patients and adjust the treatment plan accordingly [28]. Three models: a clinical model, a DL-based radiographic model, and an integrated model integrate both the clinical and radiological deep learning model to predict five-year implant loss risk. A factor that made the integrated model have the best prediction rate was the five-year implant loss risk. Another study by Zhang et al created a DL model for predicting implant loss using periapical and panoramic films [35]. The cross-sectional area of the implant and per-implant alveolar bone loss was evaluated, and the predictive probability was found to be 87%. These findings were in line with Huang et al. where the model helps clinicians to decide effectively on implant loss since the model accurately predicted the risk. More clinical trials with extended periods seen with the implant and more brands are necessary before fully adopting AI into clinical practice [28].

Transitioning from relativity simple models, there are artificial neural networks (ANNs), which prove very useful in modeling dependencies between numerous patient characteristics. Machine learning also confirms that ANNs are useful for predicting the outcomes of implants with regards to any factor that can be measured. But that comes with a catch—generating them can be resource-intensive and needs large data sets which is not feasible in clinical practice. On this front, deep learning (DL) models, especially convolutional neural networks (CNNs), have now become front-runners to achieve optimum levels of accuracy. Using the particular images derived from CBCT, DL models provide increased accuracy in marked anatomical regions and successful implant outcome prediction [45].

It seems that there are necessary trade-offs between the accuracy of AI technologies, their interpretability, and the ability to complete computations in a timely manner. Decision trees and random forests are simple and fast, thus can be applied for the first step of screening and as a measure of the potential risk. On the other hand, ANNs and DL models provide better accuracy rates, but they call for a lot of computational power and sometimes, their outputs may not be easily explained for clinical use [46].

Limitation.

The major drawback of our study is that it is an overview in the form of a narrative review covering majority of observational studies. The data from the summarized trials is apportioned into paragraphs and compared to each other without being pooled together. Therefore, true objectivity and subjects combined as one are impossible. A narrative review is the most recent publication that presents a complete roundup of the published evidence. Such a case can be also used for a complete examination of evidence. Since it fully disregards the hypothesis with which it is in disagreement, it does not guarantee that what is now believed to be true is true.

Conclusion.

Decision trees, random forests, Artificial Neural Networks (ANN), and Deep Learning (DL) improve diagnostics and treatment planning and introduce a powerful predictive model. These advancements favor better patient health and better efficiency in the delivery of oral health care. Thus, the further development of AI will help to bring advances in the field of dental practice and provide the patient with better outcomes, based on data analysis, that will undoubtedly increase the rates of successful implants. The consideration of utilizing artificial intelligence in dentistry is a step towards a future of enhanced efficient and accurate dental practice.

Recommendation and Future Research.

The future development of AI applications in the dental implantology is worthy to continue the principal focus of interdisciplinary cooperation involving dental practitioners, AI scientists, and software engineers. This paper has suggested several areas that warrant further research in the future, with the foremost one being related to improving the interpretability and transparency of the AI models to increase the confidence of clinicians in the models. In an era where both the size and heterogeneity of patient populations have increased, it is crucial to consider the methods of data sharing for the creation of robust cross-patient predictive models, with due regard to patient's data protection. However, considering that all this information is based on the use of natural language processing algorithms, it may be even more effective to seek synergies between different AI types of approaches and their application in a single model. Therefore, it is imperative to learn about the durability of the implementations made with the help of artificial intelligence in the clinical cases to understand whether or not those interventions are truly efficient. An increased focus on natural and natural language interfacing is likely to enable the incorporation of AI interfaces in clinical practices. In conclusion, further effort in these areas will help advance the progress of AI in becoming an everyday tool for the dental practitioner, which will then result in enhanced patient care and treatment outcomes.

Author Contributions.

All authors listed have made a substantial, direct, and intellectual contribution to the work. Each author has participated equally in conceptualizing, drafting, revisiting, and finalizing the manuscript. All authors approved the final version of the manuscript for submission and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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