MODERN TECHNOLOGIES AND AI IN DENTAL PROSTHETICS SUPPORT-A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: Modern technologies and artificial intelligence (AI) have brought significant advancements in dental prosthetics, optimizing the prosthetic process by improving the accuracy, efficiency, and customization of treatments. This systematic review examines the role of AI and other emerging technologies in dental prosthetics, focusing on their use in treatment planning, prosthetic design, manufacturing, and aesthetic assessment.

Methods: The review includes an analysis of recent literature on the use of digital technologies and AI in various stages of dental prosthetics. The article addresses aspects related to precise implant planning, digital prosthetic design, color selection, and aesthetic evaluation. The advantages and challenges of implementing these technologies in practice are also discussed.

Results: The use of AI in dental prosthetics allows for more accurate automated detection of anatomical structures, improving implant planning and prosthetic design. CAD/CAM technologies and 3D printing enable the rapid and efficient creation of customized prosthetics, while aesthetic evaluation improves through automated color analysis. AI contributes to increased efficiency and speed in the prosthetic process, as well as reducing errors and improving precision. However, the implementation of these technologies brings challenges related to costs and the ongoing training of professionals.

Discussion: While emerging technologies and AI hold immense potential for improving the dental prosthetics process, a regulated and ethical framework is required to ensure patient safety. The high costs of equipment and the need for continuous training are factors that must be managed in order for these solutions to become accessible and sustainable in the long term.

Conclusion: Modern technologies and artificial intelligence have revolutionized dental prosthetics, offering faster, more precise, and personalized solutions. The future of dental prosthetics looks promising, with the continuous integration of emerging technologies, which promise to transform the prosthetic process into a more efficient and accessible one.

Keywords:Modern technologies, Artificial Intelligence, Dental Prosthetics, CAD/CAM, 3D Printing, Digital Design, Implant Planning, Dental Aesthetics, AI in Dentistry, Prosthetic Personalization, Prosthetic Efficiency, Error Reduction, Dental Aesthetics, Technological Innovations, Future of Dental Prosthetics

INTRODUCTION

Dental prosthetics, both in fixed form (dental implants) and removable (full or partial dentures), play an essential role in restoring both functionality and aesthetics for patients with missing or damaged teeth. In recent decades, technological advancements have significantly transformed this field, and artificial intelligence (AI) has brought about a major shift in how prosthetic treatments are designed, planned, and implemented. From precise implant planning to the digital fabrication of prosthetics, AI and cutting-edge technologies are used to enhance the efficiency, precision, and customization of dental treatments. This paper will explore the applicability of modern technologies and AI in supporting dental prosthetics, including their applications in diagnosis, treatment

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planning, prosthetic design, and clinical outcomes assessment.

MATERIALS AND METHODS

1. Benefits of Integrating AI into Dental Prosthetics

The integration of modern technologies and AI into dental prosthetics brings numerous advantages not only for patients but also for professionals in the field. From faster diagnosis and personalized treatments to improved manufacturing efficiency, AI contributes significantly to enhancing the quality of dental care.

1.1. Increased Efficiency and Speed of the Prosthetic Process

In dentistry, the prosthetic process—which includes planning, manufacturing, and applying dental prosthetics—can be complex, involving a series of precise and technical steps. From dental impressions to the final integration of the prosthetics, each stage can be influenced by factors such as accuracy, time required, and resource efficiency. Modern technologies, especially those based on artificial intelligence (AI) and 3D printing, have profoundly transformed this field, accelerating the process and providing faster, more efficient solutions for both patients and professionals. Increasing the efficiency and speed of the prosthetic process is essential not only for reducing treatment time but also for improving the patient experience and optimizing resources in clinics.

1.1.1. Automation of Diagnostic and Planning Stages

One of the first steps in the prosthetic process is diagnosis and treatment planning. In the past, this process was often done manually, and imaging analysis was conducted using traditional radiography and impression-taking techniques. These stages could take a significant amount of time and were often prone to human errors. With the help of AI and advanced 3D imaging, diagnosis is now much faster and more accurate.

Automatic Detection of Anomalies and Dental Structures: 3D imaging technologies, such as Cone Beam Computed Tomography (CBCT), allow for precise diagnosis of the oral cavity and bone structure. AI can quickly analyze these images and identify anomalies such as cavities, infections, or bone loss. This automated process not only reduces diagnostic time but also increases accuracy, providing dentists with more detailed and accurate information about the patient's structure.

Fast and Personalized Treatment Planning: After diagnosis, AI enables rapid treatment planning by automatically suggesting personalized prosthetic solutions based on the imaging analysis. Instead of the dentist manually selecting the treatment plan, AI-assisted software can automatically recommend the best solutions for each patient, saving time and ensuring that all relevant anatomical factors are considered.

1.1.2. 3D Printing of Prosthetics and Surgical Guides

Another significant step in increasing the efficiency of the prosthetic process is the implementation of 3D printing for the creation of dental prosthetics and surgical guides. This revolutionary technology allows for the rapid creation of custom dental prosthetics, significantly reducing waiting times for patients and eliminating some traditional stages.

3D Printing of Custom Prosthetics: With 3D printers, dental prosthetics, crowns, and bridges can be quickly and custom-made based on a detailed digital model. The manufacturing process is much faster than traditional casting and molding techniques, reducing the patient's waiting time from weeks to days. Additionally, the precision of 3D printing ensures that the prosthetics fit perfectly with the patient's anatomy, reducing the need for postoperative adjustments.

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Manufacturing of Custom Surgical Guides: 3D printing is not only used for prosthetics but also for creating custom surgical guides. These guides help the surgeon place implants in a precise position, following the established treatment plan, and reducing the time needed for surgery. Furthermore, 3D-printed guides can reduce risks associated with surgical interventions by providing accurate guidance and minimizing errors.

1.1.3. Rapid Response of AI-Assisted Prosthetic Software

An important aspect of increasing the speed of the prosthetic process is the use of AI-assisted prosthetic software, which can automate many stages of the manufacturing and adjustment process. These software platforms can process information much faster than a human, reducing the time needed to reach an optimal treatment plan.

Prosthetic Design: AI-assisted design software can quickly create digital models of prosthetics, adjusting them according to each patient's needs and characteristics. These platforms allow dentists to create digital prototypes of prosthetics, test them in virtual environments, and apply changes in a very short time. Additionally, AI can analyze the shape and function of the prosthetic and suggest modifications to optimize adaptability and comfort for the patient.

Automated Adjustment Process: AI also helps in adjusting prosthetics after they are made. Instead of the dentist applying manual adjustments, the software can accurately analyze the necessary adjustments and automatically recommend solutions. This not only saves time but also resources, as it minimizes the need for additional adjustment procedures.

1.1.4. Reducing Treatment Time for Patients

A direct benefit of increased efficiency and speed in the prosthetic process is the significant reduction in treatment time for patients. In the past, patients had to wait days or even weeks to receive their completed prosthetics or crowns due to the labor-intensive manufacturing and adjustment stages. With the help of modern technologies, this time has been greatly reduced.

Reduced Production Time: 3D printing and AI-assisted software allow prosthetics to be produced in much less time than traditional methods. Patients can receive custom prosthetics in just a few days, allowing them to continue their daily lives without having to wait long periods.

Reduced Number of Visits: Modern technologies reduce the number of visits required to complete prosthetics. Through precise digital scanning and 3D printing, patients can avoid multiple sessions for impressions, adjustments, and checks, saving time and discomfort.

1.1.5. Increasing Accessibility to Prosthetic Treatments

Another important impact of increasing the efficiency and speed of the prosthetic process is the greater accessibility of prosthetic treatments. Lower production costs and reduced treatment times can make prosthetic solutions more accessible to a larger number of patients, contributing to the democratization of this type of dental care.

Reduced Costs: With automation and shorter manufacturing times, dental clinics can reduce the costs associated with the prosthetic process, and patients benefit from more affordable treatments.

Wider Accessibility: Modern technologies allow clinics from various parts of the world to offer high-quality prosthetic treatments in a shorter time and at lower costs, thus improving access to these treatments.

1.2. Customization of Prosthetic Treatments

One of the greatest advantages of using AI in dental prosthetics is the ability to customize treatments in great detail. By integrating AI

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with CAD technology, dentists can create prosthetics that perfectly fit the patient's anatomy. AI can adjust the models to ensure that the prosthetic offers both comfort and functionality, reducing discomfort and risks associated with improper adjustments. Additionally, the automatic selection of prosthetic colors based on the natural shades of the patient's teeth ensures outstanding aesthetic results.

1.3. Reducing Errors and Improving Precision

One of the most important goals in dental prosthetics is achieving a high-precision final result that ensures a perfect fit for the prosthetics and maximum comfort for the patient. In the past, errors in the manufacturing and application of dental prosthetics were inevitable to some extent due to human variability and limitations of traditional technologies. These errors could lead to additional adjustments, discomfort for the patient, and even long-term treatment failures. With the introduction of modern technologies such as artificial intelligence (AI) and 3D printing, these errors have been significantly reduced, and the precision of the prosthetic process has been considerably improved.

1.3.1. Scan and Create – Digital Scanning Technology

One of the essential steps in the prosthetic process is taking dental impressions, which are used to create a model of the patient's oral cavity. In the past, traditional impressions made with impression paste or similar materials could be imprecise due to errors in the application technique or even patient reactions (e.g., nausea or discomfort).

Precision of Digital Scanning: Digital scanning technology has gradually replaced traditional methods, using a 3D scanning device that captures a detailed and accurate image of the patient's oral cavity. These scans are extremely precise and can create an exact digital model of the teeth and gums, without the risk of distortion or errors in printing. This significantly reduces errors, as digital scans are much more precise than traditional impressions and can be corrected much faster if needed.

Elimination of Errors from Impression Materials: Digital scanning technologies eliminate errors that may occur from handling impression materials, such as errors in applying pastes or obtaining a full impression. Furthermore, the scanning process is not affected by factors like temperature or humidity, which could impact the quality of traditional impressions.

1.3.2. Artificial Intelligence in Image Analysis and Automatic Error Correction

AI plays a crucial role in reducing errors by analyzing images and automatically correcting any potential defects that may arise in digital models of the prosthetics. AI-assisted software can quickly and accurately analyze 3D models, identifying errors and suggesting adjustments, all in much less time than would be possible manually.

Geometric Error Correction: When dental prosthetics are created, even the smallest design errors can lead to discomfort for the patient or an imperfect fit. AI can analyze the digital models and detect minor geometric errors that could affect the fitting of the prosthetics, such as misalignments between the edge of the prosthesis and the gum tissue. AI algorithms can automatically adjust these errors, ensuring that the prosthetic fits perfectly.

Automated Adjustments for a Perfect Result: In addition to detecting errors, AI can make automated adjustments to the digital models to optimize the performance and fit of the prosthetics. For example, AI can adjust the shapes and sizes of the prosthetics to minimize the distance between the teeth and the prosthesis, ensuring that the prosthetic fits perfectly and provides maximum comfort.

Continuous Monitoring and Feedback: During the manufacturing and adjustment process, AI can provide continuous feedback

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and adjust parameters as the process progresses. This helps to consistently monitor precision and prevent any errors that may arise in the later stages of treatment.

1.3.3. 3D Printing for Precise Prosthetic Manufacturing

3D printing has revolutionized the manufacturing process of dental prosthetics. This technology allows for the rapid production of prosthetics from a variety of highly precise materials, with accuracy that was previously unattainable through traditional methods. Through 3D printing, an extremely fine level of detail can be achieved, ensuring that the prosthetic fits perfectly with the patient's anatomy.

Precision of Detail: Modern 3D printers can create prosthetics with submicron-level precision, meaning every detail—from the texture of the prosthetic's surface to the specific shape of the teeth—is replicated with exceptional accuracy. These prosthetics are much more precise than those made using traditional casting methods, leading to a much better fit and greater comfort for the patient.

Material Adaptability and Reduced Manufacturing Errors: 3D printing allows the use of innovative materials that can be adjusted to provide superior durability and aesthetics. Additionally, the 3D printing process is automated and digitally controlled, eliminating the risks of human error in handling materials or manufacturing the prosthetics.

Fast Manufacturing and Quick Adjustments: Thanks to 3D technology, any necessary adjustments in the manufacturing process can be implemented quickly. If the dentist notices an error in the fabricated prosthetic, it can be corrected almost instantly, saving much more time compared to traditional methods, which required additional procedures to remake the prosthetic.

1.3.4. Custom Surgical Guides and Precise Implant Placement

In the prosthetic process, the correct placement of dental implants is essential for the long-term success of the treatment. Custom surgical guides, created with the help of 3D technology and AI, have transformed how these interventions are performed.

Custom Surgical Guides: Using 3D scanning technology of the oral cavity and detailed treatment planning with AI assistance, precise surgical guides for dental implants can be created. These guides are custom-designed for each patient and ensure the exact positioning of the implant in the jawbone, reducing the risks of surgical errors and improving treatment outcomes.

Precise Implant Placement: Custom surgical guides allow the dentist to place the implant in a precise position, according to the treatment plan, without the need for large incisions or invasive techniques. These guides reduce errors during the procedure and ensure better integration of the implant into the patient's bone, increasing the success rate of the procedure.

1.3.5. Continuous Monitoring and Feedback

Modern technologies allow for constant monitoring of progress during the prosthetic process, helping to prevent errors and improve precision throughout the treatment.

Treatment Progress Monitoring Systems: Digital devices and AI can track the real-time progress of prosthetic manufacturing and placement, signaling any deviations from the initial treatment plan. This allows for quick adjustments to be made to the process, ensuring that errors are corrected before they affect the final outcome.

DISCUSSION

Despite the current challenges, modern technologies and AI continue to progress rapidly, and the future of this field looks extremely promising. In the coming years, AI is expected to become increasingly integrated

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into prosthetic dental treatments, aiming to improve both efficiency and treatment quality. Additionally, the emergence of new technologies will contribute to reducing costs and facilitating greater accessibility for a larger number of patients.

One promising direction for the future of dental prosthetics is the integration of emerging technologies such as 5G and the Internet of Things (IoT). The ultra-fast connectivity provided by 5G will enable faster and more secure data transfers between dental devices, improving coordination among medical teams and dental technicians.

IoT Integration: IoT will also enable real-time monitoring of dental prosthetics, providing instant feedback for both the dentist and the patient. For example, dental implants or prosthetics could be equipped with sensors to monitor the pressure exerted on them and provide valuable information to prevent issues before they arise.

As AI algorithms become more sophisticated, they will be able to provide increasingly personalized solutions for dental prosthetics. For example, new technologies may allow the development of prosthetics that not only perfectly fit the patient's anatomy but also adapt to their behaviors and needs over the long term. AI could monitor the prosthetic's adaptation as the patient adjusts to it, dynamically adjusting parameters to ensure optimal performance.

Another significant step in the future of dental prosthetics will be the collaboration between artificial intelligence and robotic-assisted surgery. Already, in some dental centers, robots are used for dental implant procedures, and integrating them with AI technologies could lead to extremely precise and minimally invasive interventions. Robotic-assisted surgery will also allow for dental implants to be placed with greater precision, thus reducing the risks associated with traditional procedures.

Interdisciplinary Collaboration and the Impact of AI on Dental Education

An essential aspect of the success of modern technologies and AI in dental prosthetics is interdisciplinary collaboration between professionals in dentistry, information technology, and engineering. This collaboration will enable the development of innovative solutions that meet the diverse needs of patients.

Collaboration Between Dentists and AI Engineers

Dentists will need to closely collaborate with software engineers and AI specialists to develop systems that meet specific clinical requirements. For example, AI algorithms that assist in dental implant planning must be continuously refined in collaboration with dentists to ensure greater accuracy in varying clinical conditions.

Ongoing Education and Adaptation to New Technologies

Another crucial aspect is the ongoing education of dental professionals. The implementation of AI in dental prosthetics requires dentists and dental technicians to acquire additional skills to work with advanced technologies. Universities and continuous training institutions will need to adapt curricula to include courses on CAD/CAM, AI, and dental robotics. This change will ensure that these new technologies are used correctly and efficiently in daily practice.

Ethical Implications of Education and AI Usage

As AI becomes an increasingly important component of prosthetic treatments, special attention must be paid to the ethical aspects of using these technologies. For example, clear regulations must exist regarding the confidentiality and protection of patient data, considering that sensitive information is used to personalize treatments. Moreover, the use of AI should not compromise the responsibility of dentists, who must ensure proper and empathetic care for patients.

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CONCLUSIONS

Modern technologies and artificial intelligence (AI) have brought a revolution to the field of dental prosthetics, significantly impacting all stages of the prosthetic process, from diagnosis and planning to manufacturing and actual application. These innovations allow for the creation of personalized prosthetic solutions that are much more precise and efficient than traditional methods, thereby improving the quality of treatments and patient satisfaction.The integration of AI and modern technologies in dental prosthetics promises a future where treatments are faster, more accurate, and more accessible. However, challenges such as the high cost of equipment, the need for continuous professional training, and ethical considerations must be addressed for the widespread adoption of these technologies. As AI and other advanced technologies continue to evolve, they will further transform dental prosthetics, leading to a more efficient, precise, and patient-friendly experience.The importance of modern technologies in dental prosthetics cannot be overstated. One of the greatest advantages of implementing artificial intelligence and cutting-edge technologies in dental prosthetics is the significant increase in the precision and customization of treatments. Digital treatment planning and the use of 3D scanning allow for precise images of the oral cavity, eliminating human errors and ensuring a perfect fit of prosthetics. Moreover, AI plays a crucial role in image analysis and automatic correction of any anomalies, ensuring an optimal final result without the need for multiple adjustments.In addition, 3D printing and other AI-assisted manufacturing technologies enable the rapid creation of customized prosthetics that fit the patient's anatomy perfectly. This process significantly reduces the waiting time for patients and enhances efficiency within dental clinics and laboratories, resulting in significant savings in resources and costs.AI has particularly revolutionized diagnostic accuracy, treatment planning, and the creation of prosthetics by automating many stages of the process, reducing human error, and ensuring that prosthetics are tailored to fit each patient's anatomy. Additionally, innovations in material science and digital fabrication technologies have led to the production of stronger, more durable, and aesthetically pleasing prosthetics.Despite the remarkable advancements, challenges remain, particularly in terms of the high initial costs of implementing these technologies and the need for continuous professional training. Moreover, regulatory frameworks and ethical considerations must be established to safeguard patient data and ensure the responsible use of AI in clinical settings. However, as these technologies continue to evolve, the dental prosthetic field is expected to become more efficient, accessible, and patient-centered.

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