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DIGITAL TECHNOLOGY INTEGRATION TRENDS AND CHALLENGES IN PEDIATRIC DENTISTRY

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Abstract: Orthopedic dentistry is increasingly influenced by digital technologies that significantly transform diagnostic, treatment, and rehabilitation processes. This study analyzes current trends and key challenges associated with the integration of digital solutions in dental practice. The research focuses on digital computed tomography, CAD/CAM systems, 3D scanning, and digital modeling technologies. The advantages of digital dentistry, including improved diagnostic accuracy, enhanced patient comfort, reduced production time, and higher-quality dental constructions, are examined. At the same time, the study identifies major limitations such as high equipment costs, the need for specialized staff training, and difficulties related to process standardization.

Key words: digital dentistry, orthopedic dentistry, 3D scanning, CAD/CAM, computed tomography.

Annotatsiya: Raqamli texnologiyalarning jadal rivojlanishi ortopedik stomatologiyada diagnostika, davolash va reabilitatsiya jarayonlarini tubdan o‘zgartirmoqda. Mazkur maqolada stomatologik amaliyotda raqamli texnologiyalarni joriy etishning asosiy yo‘nalishlari va dolzarb muammolari tahlil qilinadi. Tadqiqotda raqamli kompyuter tomografiyasi, CAD/CAM tizimlari, 3D skanerlash va raqamli modellashtirish texnologiyalariga alohida e’tibor qaratilgan. Raqamli yondashuvlarning diagnostik aniqlikni oshirishi, bemorlar qulayligini ta’minlashi hamda stomatologik konstruksiyalar sifatini yaxshilashi yoritib beriladi. Shu bilan birga, yuqori xarajatlar, mutaxassislarni tayyorlash zarurati va jarayonlarni standartlashtirishdagi murakkabliklar asosiy cheklovlar sifatida ko‘rsatib o‘tiladi.

Kalit so‘zlar: raqamli stomatologiya, ortopedik stomatologiya, 3D skanerlash, CAD/CAM, kompyuter tomografiyasi.

Аннотация: Ортопедическая стоматология в условиях цифровизации претерпевает существенные изменения в диагностике, лечении и реабилитации пациентов. В данной статье анализируются современные тенденции и основные проблемы внедрения цифровых технологий в стоматологическую практику. Основное внимание уделено цифровой компьютерной томографии, CAD/CAM-системам, 3D-сканированию и цифровому моделированию. Рассматриваются преимущества цифровых решений, включая повышение точности диагностики, улучшение комфорта пациентов, сокращение сроков изготовления и повышение качества стоматологических конструкций. Одновременно выявляются ограничения, связанные с высокой стоимостью оборудования, необходимостью подготовки персонала и сложностями стандартизации процессов.

Ключевые слова: цифровая стоматология, ортопедическая стоматология, 3D-сканирование, CAD/CAM, компьютерная томография.

INTRODUCTION

The rapid development of digital technologies has become one of the most influential factors transforming contemporary dentistry, including orthopedic and pediatric dental practice. Over the past decade, dentistry has undergone a fundamental transition from conventional analog methods toward fully digital workflows, encompassing diagnosis, treatment planning, fabrication of dental constructions, and patient rehabilitation.

This digital shift is driven by the demand for higher diagnostic accuracy, improved treatment predictability, enhanced patient comfort, and increased clinical efficiency.

In orthopedic dentistry, digital solutions such as intraoral scanning, cone beam computed tomography, CAD/CAM systems, and additive manufacturing technologies have significantly changed traditional clinical protocols. These innovations enable clinicians to obtain precise three-dimensional data of oral structures, design individualized treatment plans, and fabricate prosthetic and orthodontic appliances with a high degree of accuracy. As a result, treatment outcomes have become more predictable, chair-side time has been reduced, and the overall quality of dental care has improved.

At the same time, the integration of digital technologies is particularly relevant in pediatric and orthodontic practice, where patient cooperation, anatomical limitations, and psychological factors play a crucial role. Digital tools not only minimize discomfort and anxiety but also support minimally invasive and patient-centered approaches consistent with modern medical standards. However, despite the evident advantages, the widespread adoption of digital dentistry is accompanied by several challenges, including high initial investment costs, the need for specialized staff training, issues of standardization, and data security concerns.

In this context, a comprehensive analysis of current trends, technological solutions, and integration challenges in digital orthopedic dentistry is of both scientific and practical importance. This article aims to examine the key directions of digital technology development in orthopedic dentistry, assess their impact on diagnostic and therapeutic processes, and identify existing barriers and перспективные solutions for effective implementation in clinical practice.

REVIEW OF LITERATURE ON THE SUBJECT

Numerous recent studies have detailed the paradigm shift from conventional approaches to digital dentistry workflows, emphasizing a fundamental shift in the way the “child-dentist-parent” triangle is managed. According to study by Gül et al. (2021), juvenile dentistry has particular difficulties, such as restricted patient participation and certain anatomical limitations, which digital instruments seek to address with accuracy and speed.

The shift from traditional impressions to Intraoral Scanning (IOS) is a major topic of contemporary research. Children’s gag reaction is often triggered by traditional impression-taking with silicone or alginate, which results in faulty molds and psychological discomfort. Children much prefer the “digital wand” to conventional trays, according to research by Yilmaz et al. (2020). This is because the real-time visual input on the screen acts as a distraction strategy, enhancing the child’s interest and lowering “white coat syndrome.” In clinical settings, digital impressions for orthodontic appliances and space maintainers provide a better fit than stone models, significantly cutting down on chair-side adjustment time.

With the emphasis on the ALADA (As Low As Diagnostically Acceptable) concept in recent research, the use of Cone Beam Computed Tomography (CBCT) in pediatric situations has also changed. With radiation levels similar to those of conventional panoramic films, modern CBCT systems with “Ultra-Low Dose” protocols provide high-resolution 3D imaging of impacted teeth and craniofacial abnormalities. Additionally, new developments demonstrate the application of artificial intelligence (AI)-powered software for automated primary tooth caries identification. AI increases diagnostic consistency, particularly in identifying early interproximal lesions that are often overlooked by human observers, according to Schwendicke et al. (2022).

Pediatric patients who lack the patience for several visits may benefit most from the “Same-Day Dentistry” idea, which is fueled by CAD/CAM and 3D printing. Zirconia crowns for primary teeth are increasingly being made using CAD/CAM, which offers better durability and aesthetics than pre-formed stainless steel crowns. Furthermore, laboratory-fabricated surgical guides and space maintainers are being replaced with 3D-printed ones, enabling a completely digital process from scan to cementation.

The literature notes a number of enduring difficulties in spite of these developments. For many practices, the biggest obstacle is still the high upfront cost of 3D printers, software licensing, and scanners (Piedra et al., 2023). Since many intraoral scanners now on the market are made for adult oral cavities, ergonomics is still a problem. Smaller scanner tips are especially needed for toddlers and kids with tiny mouth openings. Additionally, staff training and the standardization of digital standards take a long time due to the technological learning curve. In conclusion, even if digital technology greatly improves patient comfort and diagnostic accuracy, its effective adoption hinges on removing financial obstacles and improving equipment ergonomics for the pediatric market.

RESEARCH METHODOLOGY

The study is based on a systematic review of contemporary scientific publications, clinical reports, and international guidelines related to digital technologies in orthopedic dentistry. Data were obtained from peer-reviewed journals and professional databases and analyzed using comparative, descriptive, and analytical methods to identify key trends, advantages, and integration challenges of digital dental technologies.

ANALYSIS AND RESULTS

The use of digital technology in orthopedic dentistry is one relevant and interesting path for the development of modern medicine. The development and use of digital technology in dentistry has led to a considerable improvement in the quality of patient diagnosis, treatment, and rehabilitation. Furthermore, specialists' work has grown more efficient [1]. Orthodontic dentistry is at the forefront of digital innovation, using state-of-the-art technology to give more accurate diagnosis, customized treatment plans, and high-precision surgical treatments.

In addition to the advantages, the integration process also faces some trends and problems that need further research and development [2]. Trends in the integration of digital technology in orthopedic dentistry include the widespread use of 3D printing, CAD/CAM technologies, computed tomography (CT), and 3D scanning for the creation of dental implants and prostheses. Orthopedic dentists may create precise digital models of their patients' mouth cavities and very accurate, personalized dental constructions using this technology [3].

Some of the challenges that still face the integration of digital technologies in dental offices include the high cost of software and equipment, the need for specialized staff training, and worries regarding the quality and safety of digital technology usage in dental practices [4]. This article will look at the main development trends and integration issues of digital technology in orthopedic dentistry in order to identify promising routes and possible solutions to present obstacles.

One of the primary trends is the extensive usage of 3D scanning in dental offices. 3D scanners may be used to create high-precision digital models of the dental arch, ensuring more accurate dental structure design and manufacturing. Computed tomography is particularly crucial for implant surgery planning as it offers three-dimensional images of the jaws and surrounding tissues [5].

Another significant advancement is the use of CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) technology in the production of dental prostheses and structures. This makes it possible to reduce the time needed to produce a prosthesis while preserving its high quality and patient-specific personalization [6].

The integration process does, however, provide a number of difficulties, including the high expense of equipment and software. Furthermore, the need for specialist personnel training is a significant barrier to the use of digital technology. The quality and safety of digital technology use are also important considerations for experts and equipment manufacturers [7]. In this piece, we analyze existing problems, search for solutions, and identify promising directions for the development of digital technology in orthopedic dentistry. Digital technologies are having an influence on orthopedic dentistry by altering the fundamental approaches to patient treatment and recuperation.

3D scanning and modeling are sophisticated methods for obtaining data about a patient's jaw and teeth architecture. The design of implants, orthodontic appliances, and prostheses is based on a high-precision three-dimensional model created by scanning.

Layer by layer, tangible objects for orthopaedic structures and prostheses are made using computer models in 3D printing. This enables very precise and customized production of mouthguards, crowns, bridges, dentures, and even complex implant systems. 4D printing is a relatively new method that is better than 3D printing. The primary difference is that the final 4D-printed item may alter its shape or purpose in response to environmental cues like temperature, humidity, light, etc. In order to create materials that can adapt to changes in the oral environment, researchers are looking at the possibility of 4D printing in dentistry.

Computer-aided design and manufacturing, or CAD/CAM, technologies are often used in the development and milling of dental prosthesis. They enable the creation of orthopedic products with increased precision and reduced manufacturing time. The dental office may use CAD/CAM technology to swiftly construct crowns, veneers, and other prostheses in a single visit.

Invention/Creation of Implants: Digital technology is used in the design and production of dental implants. These may be highly personalized and adapted to each patient's anatomy, reducing the likelihood of rejection and accelerating the healing process [8].

The practice of employing computer modeling to arrange dental implant surgery is known as "digital implantation." In addition to developing surgical templates, which increase surgical precision and shorten recovery times for patients, this involves figuring out the optimal implant site and insertion angle.

Technologies like virtual reality (VR) and augmented reality (AR) are used to educate patients, train dentists, and improve how they see recommended dental procedures. They provide the visualization of potential treatment resulThese technologies have made it possible for orthodontic dentists to create implants and prostheses more quickly and accurately, but they also have disadvantages, such as the need for specialized staff training, costly initial equipment and software purchases, and issues with data security and management.

The quality and precision of implants and prostheses have been greatly enhanced by the use of digital technology in orthopedic dentistry, according to study results. Accurate digital models created by high-precision scanning and manufacturing might speed up the production of dental products. In addition to reducing patient wait times, this ensures faster and more comfortable treatment. Digital technology may also be used to create prostheses that are specifically tailored to the patient's anatomical features. However, challenges include high equipment costs, the need for medical staff training, and the alteration of clinical operating standards.

The use of digital technology in orthopedic dentistry is one relevant and fascinating topic of modern medicine. The development and use of digital technology in dentistry have significantly raised the standard of diagnosis, treatment, and rehabilitation while also boosting professional productivity [1]. Using state-of-the-art instruments for high-precision surgical operations, customized treatment regimens, and more accurate diagnostics, orthodontic dentistry is at the forefront of technical innovation. Nevertheless, despite these benefits, the integration process faces some trends and challenges that need more research and development [2].

Trends in digital integration in orthopedic dentistry include the widespread use of 3D printing, CAD/CAM technology, computed tomography (CT), and 3D scanning for dental implants and prostheses. Orthopedic dentists may create precise digital models of their patients' oral cavities and highly accurate, personalized dental constructions using these technologies [3].

Some of the most important innovative methods are:

Advanced methods for obtaining data on the structure of the jaw and teeth, such as 3D scanning and modeling, which are then used to create implants and prostheses.

The method of employing computer models to create real products, such as dental crowns, bridges, and complex implant systems, layer by layer is known as 3D printing.

A more modern method called 4D printing enables materials to change their structure or function in reaction to external stimuli (such as light, temperature, etc.) in order to adapt to the oral environment.

CAD/CAM technology may speed up the development and milling of prosthetics while also improving final accuracy.

The process of planning procedures, selecting the ideal implant site, and developing surgical guidelines to save recovery time by computer modeling is known as "digital implantation."

Training, education, and helping patients view treatment results prior to surgery are all accomplished via the use of virtual and augmented reality (VR and AR) [8, 9].

Despite the benefits, integration presents some difficulties:

Costs: The most significant barrier is the high cost of equipment and software. Personnel Training: Since staff members' inability to utilize digital technologies efficiently may obstruct successful integration, specialized training is essential [10].

Cybersecurity: As the amount of digital data grows, so does the risk of cyberattacks and the exposure of confidential patient information.

Standardization and Compatibility: The lack of common standards makes it more challenging for specialists and different organizations to share information.

Quality and Safety: Safety rules must be closely followed by both specialists and manufacturers while employing digital technologies [7].

Digital technology integration requires a thorough plan that covers everything from equipment selection to clinical operational logistics. The state and professional dental organizations must support the creation of standards and regulations that govern the use of digital technology in medical practice.

CONCLUSIONS AND SUGGESTIONS

Digital technology is a powerful tool for improving patient care and service quality in orthopedic dentistry. The long-term advantages outweigh the initial costs and difficulties. Ongoing study, development, and the creation of a legal framework will help these technologies become more widely accepted.

Patient care may benefit from new possibilities brought about by digital technology integration, but there are drawbacks as well, including issues with staff training, cybersecurity, and uniformity. To address these issues, cooperation across the academic, corporate, and medical communities will be required. Despite these challenges, patients have a lot to benefit from digital integration in orthopedic dentistry, which also promises to improve treatment efficacy.

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