DIGITAL TECHNOLOGIES IN AESTHETIC DENTISTRY: TOOLS FOR PLANNING AND EXECUTING RESTORATIVE TREATMENTS

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Abstract. This study aims to evaluate the available technologies and their applications, advantages, disadvantages, and future perspectives. Integrative literature review on the use of digital tools with a focus on restorative procedures, conducted through research in the PubMed, Lilacs, and Cochrane databases in May 2024, in English and Portuguese. Of the 193 articles found in the search, 46 studies in English and Russian were included in this review after analysis. In these studies, several categories of technologies were identified for various purposes in aesthetic planning and treatment, such as: software, scanners, tomographs, 3D printers, chairside systems, as well as artificial intelligence (AI) and augmented reality (AR). The digital workflow offers reduced clinical time, predictability, and precision in planning and treatment but does not eliminate the need for clinical judgment, experience, and mastery of the tools.

Keywords: dentistry; operative dentistry; digital; technology; planning.

Resumo. Este estudo visa avaliar as tecnologias disponíveis e suas aplicações, vantagens, desvantagens e perspectivas futuras. Revisão integrativa da literatura sobre o uso de ferramentas digitais com foco em procedimentos restauradores, realizada por meio de pesquisa nas bases de dados PubMed, Lilacs e Cochrane em maio de 2024, nos idiomas inglês e português. Dos 193 artigos encontrados na pesquisa realizada, 46 estudos nos idiomas inglês e russo foram incluídos nesta revisão após análise. Nestes trabalhos, foram identificadas várias categorias de tecnologias utilizadas para diversos fins no planejamento e tratamento estético, como: softwares, scanners, tomógrafos, impressoras 3D, sistemas chairside, além de inteligência artificial (IA) e realidade aumentada (RA). O fluxo digital de trabalho oferece redução do tempo de atendimento clínico, previsibilidade e precisão no planejamento e tratamento, mas não elimina a necessidade de julgamento clínico, experiência e domínio das ferramentas.

Palavras-chave: odontologia; dentística; tecnologia; digital; planejamento.

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INTRODUCTION

Smile aesthetics has become a determining factor in self-esteem, well-being, and social status. In this context, the various specialties of dentistry have played a fundamental role in rehabilitating, promoting health, and improving aesthetics. Aesthetic dentistry is not a distinct discipline or area of dentistry, but rather encompasses various specialties, including dentistry, prosthodontics, orthodontics, periodontics, and oral and maxillofacial surgery. [1]

Among these areas, dentistry is responsible for promoting preventive and/or restorative treatments that result in the maintenance or re-establishment of form, function, and aesthetics, maintaining the physiological integrity of the tooth. [2]

In dental practice, traditional techniques and analog tools serve as the basis for the advent of digital tools. Software applications, scanners, 3D printers, chairside systems, and other tools enable a comprehensive digital workflow, supporting patients from diagnosis to treatment completion. In the context of progressive technological advances and the frequent introduction of innovative tools on the market, a crucial question arises: How can these tools facilitate planning and treatment in aesthetic dentistry?

Therefore, this integrative review aims to evaluate the most used digital technologies in aesthetic restorative treatments and their applications, providing a deeper understanding of the current scenario, its advantages, disadvantages, and future prospects.

MATERIAL AND METHODS

In order to develop this integrative literature review, a bibliographic search was conducted using articles available in the PubMed, Latin American and Caribbean Health Sciences Literature (LILACS), and Cochrane Library databases in May 2024. The following descriptors were used in the English language repositories: “dentistry,” “operative dentistry,” “planning,” “digital,” “treatment,” and “design.” The exact search was conducted in Portuguese (“odontologia,” “dentística operatória,” “planejamento,” “digital,” “tratamento,” and “design”) across the three databases, spanning the years 2004 to 2024.

The results from each repository were imported into the Rayyan analysis platform in RIS format, where duplicate files were automatically detected and removed. Two trained and calibrated researchers then independently analyzed the titles and abstracts to first screen the articles found.

The selected articles were read in full by the same researchers to apply the inclusion criteria: the text was available to read in full, the approach involved digital tools, the focus was on dental aesthetics, and the relation to dentistry was evident. Exclusion criteria were articles limited to the areas of prosthodontics, endodontics, implantology, orthodontics, and oral and maxillofacial surgery. In decisions where a conflict of classification arose, the evaluators debated and classified by consensus.

RESULTS AND DISCUSSION

A total of 193 studies were found on the PubMed, Lilacs, and Cochrane Library platforms. We obtained 145, 36, and 12 articles in English and Russian, respectively. After excluding 16 duplicate articles, 177 were included for reading the title and abstract, with 62 articles selected for full reading and final selection.

Of the 16 articles removed, 6 had an emphasis on oral rehabilitation using total or partial prostheses. 4 articles were not available to read in full, 5 dealt only with implant dentistry. 1 article did not report on the use of digital technologies and was also removed from the research. After reading it in full, 46 articles published between 2011 and 2024 were selected for this study.

From the articles studied, it is evident that the technologies identified aid dental professionals in their daily work and are therefore considered health technologies. According to the World Health Organization3, a health technology is "the application of knowledge and skills organized in the form of devices, medicines, vaccines, procedures, and systems developed to solve a health problem and improve quality of life".

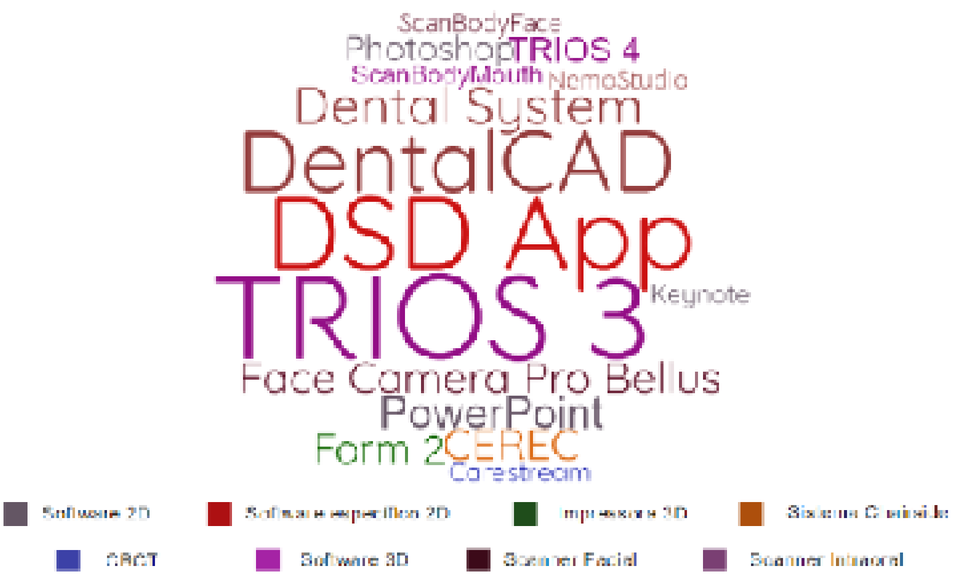
According to Merhy[4], the technologies involved in health work can be classified as follows: soft (relationship technologies, such as bonding and welcoming), soft-hard (well-structured knowledge, such as epidemiology and Taylorism), and hard (the use of technological equipment). Complex technology can be understood as the application of high technology, including machines, software, and videos. [5]

Initially, digital dentistry was primarily limited to the printing and fabrication of restorations.[6] Today, the digital workflow begins with diagnosis and treatment planning, where the first steps include intraoral and extraoral scans and radiographic analysis.

For Vale Voigt et al.[7] planning is a fundamental component for the success of any medical treatment, especially when it comes to aesthetics.

To understand how digital technology assists the practice of the modern dental surgeon, this paper provides an overview of the most commonly used complex technologies, including software, scanners, 3D printers, chairside systems, virtual articulators, computed tomography, artificial intelligence, and augmented reality.

FIGURE 1: Most used tools according to the number of citations.



Source: Authors, 2024.

DIGITAL TECHNOLOGIES

Software Applications 2D

2D software has been widely reported in the literature as an option for facilitating aesthetic interventions. Studies by Piedra-Cascón et al.8 describe the use of image editing and presentation software as a tool for planning dental rehabilitation.

In this context, the use of this software also facilitates better communication between the professional and the patient, enabling the patient to preview the results of the proposed procedure and play an active role in choosing their new smile with the dental surgeon.

Non-Specific 2D Software

Non-specific software, although not specifically developed for dental practice, offers an economic advantage over specialized software, as it can be used to plan aesthetic interventions at a lower cost.9 These tools can process 2D data (extraoral and intraoral photographs, radiographs), enabling professionals to take measurements, make drawings, and design projects, and also present the patient with the prospects of the aesthetic intervention, as they can be involved in planning the design of their new smile.[9]

One example is the image-editing software described by Goodlin[10], Photoshop (Adobe, San Jose, California, United States), which has some functionalities relevant to clinical practice: covering imperfections (stains and old restorations), sharpness filters (clarity in details), and altering the height and width of objects (adjustments to the proportion of teeth).

Other non-specific 2D software applications found in the literature are Keynote (Apple Inc., Cupertino, California, United States) and PowerPoint (Microsoft Corporation, Redmond, Washington, United States). Despite having more generic and limited functionalities, both can be used on most devices (computers, tablets, and cell phones).

However, by providing only a 2D approach, it is necessary to combine the digital planning carried out in these software applications with conventional procedures such as diagnostic molding and dental waxing.[8]

2D Specific Software Applications

Specific 2D software applications are developed exclusively for the clinical practice of the dental surgeon. These have functionalities that enable a range of possibilities for planning and executing treatments.

DSDapp (Digital Smile Design, DSD App LLC, Madrid, Spain), developed by Brazilian dentist Christian Coachman, was the most frequently used 2D dental software for planning aesthetic treatments.

A highly relevant clinical application cited by Piedra-Cascón et al.[8] is the possibility of performing the diagnostic wax-up virtually, thereby generating a photorealistic simulation of the final treatment result. This advantage increases the levels of acceptance of the treatment, as the patient is involved in the smile development process.[9]

The use of the DSDapp enables greater predictability of treatment outcomes, analysis of dentofacial proportions, and facilitates communication with patients, as well as providing a library of smile “templates” from which to choose various dental shapes. However, the use of the DSDapp requires professional training and skill to ensure its effective use.[7]

Among other 2D software, the Smile Cloud Biometrics platform (SmileCloud, Dentcof, ADN3D Biotech srl, Timisoara, Romania) is a viable option for aesthetic case planning. This 2D software utilizes artificial intelligence to suggest shapes, colors, and sizes based on the patient's facial features.[8]

Among the software's advantages, cloud data storage is a feature that enables asynchronous communication and interaction between different professionals involved in treatment planning and design.[11] Although some data can be exported in STL(Standard Triangulation Language, a format that can be imported into 3D platforms), specific 2D software does not really integrate with these devices. Additionally, another disadvantage is that using these tools requires a significant financial investment.[8]

Software Applications 3D

The integration of different digital technologies has the capacity to facilitate the development of a 3D virtual patient, allowing for the design of a smile that agrees with the patient's face.12,13 Programs that utilize photographs and scans of the dental arch enable the dental surgeon to design a personalized virtual smile for each patient, while simultaneously evaluating both aesthetics and function.14

Non-Specific 3D Software Applications

Although developed for general purposes, non-specific 3D software applications can still be beneficial to dental practices, particularly when it comes to planning. Among the most cited are Blender (The Blender Foundation, Amsterdam, Netherlands) and Meshmixer (Autodesk, San Rafael, California, United States).

Blender is a non-specific open-source 3D software, meaning that different tools can be added using the program's base code as a reference. As a result, plug-ins are incorporated into the base program, adding functionalities designed explicitly for the dental area, thereby creating a new type of software.[8] Using Blender for Dental, it is possible to import 2D data (photographs, radiographs) and 3D data (obtained by scanners and computed tomography). To process this data, the software features design and diagnostic tools, allowing for the creation of digital wax-ups and the use of a virtual articulator. The advantage of this software is its low cost of use.

Another software program seen was Meshmixer (Autodesk, San Rafael, California, United States), which can be used to analyze and edit 3D virtual meshes. The program is free and allows you to import different libraries of dental arches used to make digital models.

Specific 3D Software Applications

As an advantage over 2D software applications, these programs can be used to prepare a 3D diagnostic wax-up, which in turn enables the production of provisional restorations or silicone guides by additive manufacturing (AM) and milling.[8]

Among the most widely used software applications are DentalCAD (Exocad, Darmstadt, Germany) and Dental Systems (3Shape, Copenhagen, Denmark). The Dental Systems software (3Shape, Copenhagen, Denmark) was used in the study by Revilla-Leon et al.[15] for digital diagnostic wax-up preparation, soft and hard tissue measurement, digital silicone guide preparation, and laminate design.

With a more intuitive interface for dental professionals compared to open-source software applications, DentalCAD offers functionalities for various areas of practice and has unlimited applications for virtual design. The software also provides complementary modules that cater to the specific needs of different areas of dentistry.[15]

Scanners

Scanners are tools that enable the scanning of intraoral and extraoral (facial) structures, generating 3D data of the patient. These allow STL files to be obtained, with the possibility of exporting these files for use in other devices, such as 3D printers.

Intraoral Scanners

Intraoral scanning is a direct method of acquiring digital models. Recent research has demonstrated that the intraoral scanning method is accurate and serves as an alternative to the use of plaster models.[16] As a disadvantage, although intraoral scanning reduces patient discomfort when using impression materials, there is some difficulty in changing directions and angles when scanning due to the proximity of the scanner to oral structures.[17] Zaruba and Mehl[18] describe some of the advantages of the TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark), which has been cited the most. In addition to being a cutting tool, its software can block out structures that should not change during scanning, and its STL data enables the exchange of information between the dental surgeon and the laboratory.

Facial Scanners

The use of facial scanners in treatment planning allows for three-dimensional (3D) visualization of the patient's face; however, overlaying facial scans with intraoral scans is even more efficient.[15] The use of stereophotogrammetry is described as one of the most common means of obtaining 3D facial images and is considered the gold standard.[19] Despite its many advantages, such as being radiation-free and minimally invasive, the system has a large apparatus with multiple cameras, requires frequent calibration, and is expensive. Therefore, the use of smartphones is described as an alternative to this tool for obtaining facial images.[19]

Among the studies analyzed, the stereophotogrammetry booth, clOner (dOne 3D, Ribeirão Preto, São Paulo, Brazil), is equipped with 16 cameras (8 MP; 2.8 mm each) programmed to synchronize and compose the patient's facial image.[20]

The most widely used facial scanning tool among the selected articles was the Face Camera Pro application (Bellus 3D, Campbell, California, United States). Its main advantages include its low cost and ease of use, since its software can be used from tablets or smartphones. Data from Bellus 3D showed good accuracy and reproducibility in the results, but the software requires head movements from the patient, which can lead to inaccuracies.[19]

Cone Beam Computed Tomography (CBCT)

To highlight the importance of integrating facial scanning, intraoral scanning and model scanning, Cone-Beam Computed Tomography can contribute to a digital workflow.[1] The CS9300 and CS9600 (Carestream, Rochester, New York, USA) have been the most widely reported devices.

The combination of computed tomography, scanners, and state-of-the-art software can provide an accurate representation of a virtual patient.[1]

For Culp, [21], an advantage of integrating this tool into the digital workflow is that professionals can preview, test different treatment options, combine data to develop a treatment plan, and create solutions that incorporate all the functional and aesthetic aspects of oral rehabilitation.

Although CBCT offers high-quality images, one of its shortcomings is its inability to discriminate between soft tissues, which makes it an exclusive tool for imaging hard maxillofacial tissues.[22] Although the files obtained through CBCT are in DICOM (Digital Imaging and Communications in Medicine) format, it is possible to convert them to STL format, allowing integration with software and 3D printers.[23]

3D Printers

3D impressions integrated into the digital workflow are considered fundamental for the fully digital approach to treatment planning.24 Among some applications of this technology, the use of 3D printers can be applied to the fabrication of provisional restorations, the printing of guides for wear and tooth preparation, providing a minimally invasive and precise intervention.[25]

Specific characteristics of 3D printer implementation in dental practice are described in the literature. Clinical applications of 3D printing include occlusal splints, orthodontic therapy with transparent aligners, study models for diagnosis and treatment planning, and provisional restorations.[23]

Moshman[23] points out that 3D printing has a steep learning curve, as well as a plan to incorporate its use into clinical practice, in addition to the high financial cost associated with it. The most common 3D printer in the studies collected was the DLP-type Form 2 (FormLabs, Somerville, Massachusetts, United States).

Chairside Systems

The first generation of CAD/CAM (scanner and software/milling machine) was designed to fabricate immediate inlay and onlay ceramic restorations, but offered a limited 2D version of the scanned images.[26]

According to Zaruba and Mehl[18], Chairside is a concept for fabricating dental restorations directly after tooth preparation during a single appointment. Most of today's chairside systems are open, allowing them to be integrated with other tools. This is advantageous since, in some cases, the internal milling machine of the chairside system in question may not be capable of using another type of material or a specific restoration.

The chairside systems most cited in the papers include Carestream (Rochester, New York, United States) and CEREC AC (Dentsply Sirona, New York, New York, United States). The CEREC system has design-added software, making it intuitive and easy to use. Its features include margin marking, virtual projection of the restoration's digital wax-up, precise definition of occlusal contacts, and refinement of proximal contact areas.26

FUTURE PROSPECTS

Artificial Intelligence (AI)

The use of AI and ML (machine learning) has a growing impact on the dental profession and complements the development of digital technologies and tools.[27]

New AI techniques have enabled the extraction of detailed information from collected data. This process of extracting information is often referred to as ML, the data-driven component of AI, which enables machines (algorithms running on computer systems) to learn about a specific topic from a given set of available data. [27, 28]

The DSDapp software claims to utilize AI algorithms, allowing for the manual segmentation and measurement of teeth, as well as the superimposition of the desired new teeth. Part of this workflow can be automated using AI techniques. The Bellus 3D software provides automatic detection of the patient's teeth and their removal, with the possibility of manual modification; these actions are carried out using artificial intelligence.[27]

One of the applications described is related to digital planning based on artificial intelligence and was demonstrated with the VisagiSmile software (Rebel Dental, Sophia, Bulgaria). In the clinical case described, in addition to photographs and STL data, the authors also gathered information on facial features and a questionnaire about the patient's personality and personal preferences. This information was then processed to create an individualized 3D diagnostic wax-up from a 2D design.[28]

4D Technology

The creation of a 4D virtual patient is described as a technique that combines facial images, intraoral scanning, digital planning software, and virtual smile animation through the superimposition of intraoral and facial scans, along with jaw and face movements and pictures obtained by CBCT, allowing for a realistic and dynamic treatment.[20] In addition to the technologies mentioned above, Maya animation software (Autodesk, San Rafael, California, United States) is used to generate a video of the smile design in the creation of a 4D patient: a representation of 3 dimensions brought together with the patient in motion.[20]

Augmented Reality (AR)

Augmented reality is defined as a technology that superimposes virtual content on authentic images. In the clinical case described, this technology was presented to the patient to demonstrate the rehabilitation proposal in real-time.[29]

The IvoSmile software (Ivoclar Vivadent, Schaan, Liechtenstein) operates by having the patient view the screen of the respective device as if it were a magnified mirror, which in turn enables dynamic 3D analysis and smile planning.[29]

As this is a relatively new technology, the clinical protocols and methods that use it are still under development, and studies are needed to assess their accuracy.[29]

Virtual Articulator

Virtual articulators are tools that utilize technology to simulate mandibular relationships based on a computer-generated configuration. These tools are classified into two types: fully adjustable, which reproduce movements using an electronic mandibular registration system, and mathematically simulated, which reproduce movements based on the mathematical simulation of articulatory movements.[30]

Among the advantages cited by Merino[30], virtual articulators facilitate better communication between dentists and technicians, providing stomatognathic and articular information. Limitations include high costs, as well as the skill and knowledge required for the CAD/CAM system. In the selected texts, the virtual articulators cited were Modjaw (Modjaw, Villeurbanne, France) and Virtual Artex CR (Amann Girrbach, Germany).

Referência	País de Origem	Tecnologia(s) avaliada(s)
Piedra-Cascón et al. (2021)	Spain	Softwares 2D and 3D
Carrillo-Perez et al. (2022)	Spain	IA
Zaruba e Mehl (2017)	Switzerland	Chairside Systems
Blatz et al. (2019)	United States	CBCT, Softwares 2D and 3D; AI
Goodlin (2011)	Canada	Software 2D
Zimmermann e Mehl (2015)	Switzerland	Software 3D and Chairside System
Ahmed (2018)	Australia	N/A
Moshman (2021)	United States	CBCT; Software 3D; Impressora 3D
Culp (2013)	United States	N/A
McLaren, Garber e Figueira (2013)	United States	Software 2D
Coachman, Sesma e Blatz (2017)	Brazil	Smartphone
Revilla-Leon et al. (2018)	United States	Software 3D; IOS; Impressora 3D
Gao et al. (2020)	China	Software 3D; CBCT; IOS and FS; Impressora 3D
Santi, Nastri e Lins (2024)	Brazil	Software 3D; IOS; Impressora 3D
Ferreira et al. (2024)	India	Softwares 2D and 3D
Cunha et al. (2020)	Brazil	Software 2D
Mykhaylyuk, Mykhaylyuk, Blatz (2022)	Ukraine	IOS and Software 3D
Kochanowski, Barankiewicz, Sadowska e Dejak (2023)	Poland	Software 3D; IOS; Impressora 3D
Apresyan, Stepanov e Vardanyan (2021)	Russia	IA; CBCT; Software 2D
Almalki et al. (2022)	United States	Software 3D and Chairside System
Rebba et al. (2021)	Italy	IOS; Softwares 2D and 3D
Revilla-Leon et al. (2020)	United States	FS; IOS; Software 3D; Impressora 3D
Guichet (2020)	United States	Software 3D and IOS
Vale Voigt et al. (2020)	Brazil	Software 3D
Martins, Albuquerque e Santos (2017)	Brazil	Software 3D and IOS
Ntovas et al. (2023)	Greece	Software IA 3D; IOS
Jreige et al. (2020)	Brazil	FS; IOS; Software 3D; Software de Animação; Impressora 3D;
Coachman et al. (2021)	Brazil	Software 3D; CBCT; IOS; Impressora 3D
Marchand et al. (2020)	Switzerland	Software RA 3D; Impressora 3D
Abdel-Azim, Zandinejad, Metz, Morton (2015)	United States	Software 3D and IOS;
Li, Yu, Feng, Liu (2022)	China	Software 3D; IOS; Impressora 3D
Geštakovski (2021)	Croatia	IOS
Pinzan-Vercelino et al. (2017)	Brazil	Software 2D and 3D
Trushkowsky, Arias e David (2016)	United States	Software 3D
Harsono, Simon, Stein, Kugel (2012)	United States	IOS; Software 3D
Yassmin e Blatz (2022)	Austrália	Software 2D; CBCT; IOS; Impressora 3D
Harnois (2013)	United States	Software 3D; CBCT; IOS; Impressora 3D
Sabbah (2022)	United States	Software 2D; 3D; IOS;
Murugesan e Sivakumar (2020)	India	IOS and Software 3D
Camardella, Vilella, Van Hezel, e Breuning (2017)	Brazil	Impressora 3D
Revilla-Leon et al. (2021)	United States	Software 3D; CBCT; IOS and FS; Impressora 3D

Revilla-Leon et al. (2022)	United States	Software 3D; IOS; FS
Lavorgna et al. (2019)	Italy	Software 2D and 3D; IOS
Ortensi, Castro, Rapisarda e Pedullà (2020)	Italy	Impressora 3D; Software 3D
Coachman et al. (2021)	Brazil	Software 2D; CBCT; IOS; FO;
Shepperson (2023)	New Zealand	Articulador Virtual; IOS and FS; CBCT; Softwares 2D e 3D

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