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From conventional to Virtual smile design systems: a current systematic review

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Abstract: Objective: Without impacting the dental sciences, breakthroughs in technology and applications could not be accomplished. In the advancement of technology and information technology, dentistry and dental materials have been fully active, so much so that they have revolutionized dental techniques. **Material & methods;** We want to produce the first series of articles in this review on the use of digital techniques and software, such as Smile Concept Digital. The goal is to gather all the findings on the use of this program and to highlight the fields of use. The analysis included forty-nine articles, the latter discussing the use of Digital Smile Design and the area of use. The research aims to classify the dental fields are using "digitization." Change is constant in this field and will be increasing Interest in dentistry by recommending the speed and reliability of outcomes for care planning. **Conclusion:** As seen in the study, the digital workflow facilitates recovery that is reliable both from an aesthetic and functional point of view. The current area of use of Digital Smile Design techniques in the different branches of medicine and dentistry as well as knowledge have emerged from this research.

Keywords: Digital Smile Design, digital dentistry, dentistry software; dentistry design software.

1. Introduction

The careful esthetic analysis is a crucial but often challenging part of modern dentistry. Although dental proportions must fit into the basic framework conditions determined by nature, dental esthetics is and always will be subjective. Different people can have extremely different views on what makes a smile beautiful. Moreover, dental esthetics is strongly dependent on a person's emotions and personality. A smile is often a reflection of the patient's mood and temperament. Redesigning the appearance of the anterior teeth in the smile design process is a demanding task; first, because this changes the patient's smile characteristics, and second, because the esthetic wishes of the patient must be accommodated within the predetermined functional, structural, and biological framework. [1]

For all these reasons, good communication is crucial to successful smile design. If esthetic rehabilitation of the patient's smile is to be accomplished by an interdisciplinary team, the goals of treatment must be communicated to each team member to achieve the

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desired results. Particularly when doing smile makeovers, it is advisable to enhance patient communication so that the patient can not only give informed consent but also make informed decisions. This serves to increase patient motivation and involvement in the treatment process. [1]

Conventional workflows for dental esthetic rehabilitation involves adequate communication with the dental laboratory technician by using diagnostic waxing and mock-up guide [2] In this respect, it has been demonstrated that tooth preparation is more conservative when a diagnostic mock-up is used compared to the free-hand preparation. [3] Also, diagnostic wax-up enhances the communication with the patient since it shows a realistic preview of the final aesthetic restorations as well as provides clinicians with a better understanding of the patient's aesthetic expectations. [4] As consequence, patients' satisfaction with the treatment strictly depends on the consistency of the final product with the mock-up [5]. However, the in-mouth mock-up molding phase is based on complex and operator-dependent procedures. This may lead to low accuracy and inconsistency with patients' expectations, in particular, if the aesthetic result has been previously evaluated and designed following patients' needs, as occurring with the virtual planning approach [6]. In this respect, virtual planning represents a useful tool to obtain esthetic information for diagnosis and treatment plan as well as for design, fabrication, and delivery processes of the definitive restorations [7].

In the last two decades smile designing has progressively evolved from physical analog to digital designing which has advanced from 2D to 3D. From the earlier times when hand drawings on printed photos of the patient were used to communicate and explain to the patients of how the result would look like, it has now progressed into complete digital drawing on DSD software on the computer. This can be easily be edited and can be done and undone anytime to achieve the final design balancing patient's aesthetic and functional needs. [7].

Evolution of digital smile designing

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Christian Coachman in 2017 has proposed this evolution in generations as Generation 1. Analog drawings over photos and no connection to the analog model. It was the time when drawing with a pen was done on the printed copy of photographs to visualize the treatment result but that could not be correlated with the study model. Digital dentistry by now was not introduced. Generation 2. Digital 2D drawings and visual connection to the analog model. With the advent of the digital world, certain software like PowerPoint was familiarized which permitted digital drawing. Although not specific to dentistry and limited to drawing in two dimensions it was more accurate and less time consuming than hand drawing. The drawing could be visually connected to the study model, but the physical connection still lacked. Generation 3. Digital 2D drawings and analog connection to the model. This was the beginning of a digital-analog connection. The very first drawing software specific to digital dentistry was introduced which linked 2D digital smile design to 3D wax-up. Facial integration to smile design was also introduced at this stage, but a connection to the 3D digital world was missing. Generation 4. Digital 2D drawings and digital connection to the 3D model. Now was the time when digital dentistry progressed from 2D to 3D analysis. 3D digital wax-up could be done involving fa-

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cial integration and predetermined dental aesthetic parameters. Generation 5. Complete 3D workflow. Generation 6. The 4D concept. Adding motion to the smile design process.[8]

Objectives

Digital imaging and designing help patients visualize the expected result before the treatment itself starts which enhances the predictability of the treatment. [9] DSD leads to the customization of smile design by increasing the participation of the patient in their smile design which results in a more aesthetically driven, humanistic, emotional, and confident smile. [10] . It not only improves communication between clinician and patient but also between interdisciplinary team members, clinicians, clinician, and lab technician. [11]

The treatment for giving an "aesthetic smile" to patients is related to the different anatomical areas involved in the treatments, like the teeth, gingiva, mucosa, lip, skin, and so on, which rely on symmetry, shape, and golden proportions. The purpose of this study is to evaluate the effective use of Digital Smile Design techniques in dentistry. These techniques are used in different medical fields, and we have analyzed and categorized all these fields and have evaluated the reliability and predictability of these digital techniques.

2. Materials and Methods

This carefully designed systematic review was created and the results were reported according to guidance provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and the *Cochrane Handbook for Systematic Reviews of Interventions*. The protocol and research question of this current systematic review was created based on the Problem, Intervention, Comparison, Outcome (PICO) format. The protocol of the review under the registration number is:PROSPERO # CRD42021226922. You can log in to PROSPERO and access your records at https://www.crd.york.ac.uk/PROSPERO

4.1. Focus Question

The following focus questions were developed according to the population, intervention, comparison, and outcome (PICO) study design [12]

What are the shortcomings of digital smile design conventional techniques?

Is Digital Smile Design bringing improvements in the comfort of patients and their treatments?

4.2. Data Sources

The search strategy incorporated examinations of electronic databases, supplemented by hand searches. We searched PubMed, Dentistry, and Oral Sciences Source for relevant studies published in English. A hand search of the reference lists in the articles retrieved was carried out to source additional relevant publications and to improve on the sensitivity of the search. The keywords used in the search of the selected electronic databases included the following: smile design, dental Esthetic, facial esthetic, dental esthetic software, digital esthetic, and Digital Smile Design. The choice of keywords was intended

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to collect and to record as much relevant data as possible, without relying on electronic means alone to refine the search results.

4.3. Selection of Studies

Two independent reviewers singularly analyzed the obtaining papers to select the inclusion and exclusion criteria as follows. For the stage of reviewing full-text articles, a complete independent dual revision was performed. The review included studies on humans and laboratory published in English. Letters, editorials, and Ph.D. theses were excluded. The review included all human prospective and retrospective follow-up studies and clinical trials, cohort studies, case-control studies, case series studies, animal studies, and literature reviews published on using Digital Smile Design for rehabilitation and restorative dentistry.

4.4. The eligibility criteria for study inclusion were pre-determined and are summarized in Table(1).

A study was considered eligible when it reported the outcomes of at least one software known to affect the appearance of the smile or at least one treatment component known to contribute to the creation of a balanced smile. Our aim in writing this review was to gather information on smile design related to software only. Because the focus of our question was solely outcomes following software in smile design alone, studies that reported data concerning treatment strategies that included implants or treatment systems that are not considered conventional smile design methods were not included. Studies that included data on outcomes of orthognathic surgery were also excluded because orthognathic surgery in conjunction with orthodontic treatment may alter smile outcomes in ways that are not similar to the effects on smile appearance following orthodontic treatment alone.

Table (1); Criteria for Considering Studies For This Review

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Inclusion criteria	Exclusion criteria
Randomized and non-randomized clinical trials studying the effect of software on smile design	Patients with craniofacial discrepancies, cleft lip animal published in English. Letters, editorials, and Ph.D. theses were excluded.
Studies wrote in English	Orthognathic cases or Invisalign cases
Patients who underwent smile design with any type of software method	Studies investigating the perception of laypeople or specialists about smile esthetics
Observational studies Studies publicized within 2010 and 2020	Studies investigating smile esthetics from the lateral aspect rather than the frontal aspect
Duration of follow-up From 2010 till 2020	No access to the title and the abstract in English

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4.5. Sequential Search Strategy

After the first literary analysis, all the article titles were screened to exclude irrelevant publications, case reports, and non-English publications. Then, researches were not selected based on the data obtained from screening the abstracts. The final stage of screening involved reading the full texts to confirm each study's eligibility, based on the inclusion and exclusion criteria. The data were independently extracted from the studies in the form of variables, according to the aims and themes of the present review, as listed onwards. The data were collected from the included articles, and were arranged in the following fields (Table 2): "Author (Year)"—revealed the author and year of publication and "Dental Field"—the dental field of Digital Smile Design was used

4.6. Risk of Bias Assessment

Two authors assessed the risk of bias during the data extraction process. For the included studies, this was conducted using the Cochrane Collaboration's two-part tool for assessing the risk of bias [13-14]. The overall risk of bias was then assigned to each trial, according to Higgins et al. [14]. The levels of bias were classified as follows: minimal risk, if all of the criteria were met; moderate risk, when only one criterion was missing; high risk, if two or more criteria were missing; and unclear risk, if there were too few details to make a judgment about the certain risk assessment.

3. Results

The results were collected from all the articles that were taken into consideration. The articles that talk about Digital Smile Design and its use in the field of rehabilitative and restorative dentistry were used. In the article, we have not only taken into consideration the "communicative" utility of the software towards the patients, but also that of therapeutic planning and aesthetic and functional rehabilitation. The articles included in our review already provide valuable information regarding the field of use of the current digital techniques. Surely, in the first place, the most common field of use is prosthetic and dental restoration. In second place are the positions that mention digital techniques for periodontal purposes instead. Later, we will review these works more closely. Although these techniques are modern and relatively new, the purpose of this work is not to indicate whether these techniques are reliable or not, because the available data available are still few. The aim is to highlight use-trend in different dental fields.

5.1. Study Selection

The article review and data extraction were performed according to the Preferred Reporting Items for Systematic Reviews and Metanalyses PRISMA flow diagram (Figure 1). The initial electronic and hand searches retrieved 72 articles. After the titles and abstracts were reviewed, only 94 articles were included

BAR CHART OF DATA COLLECTION AND ANALYSIS

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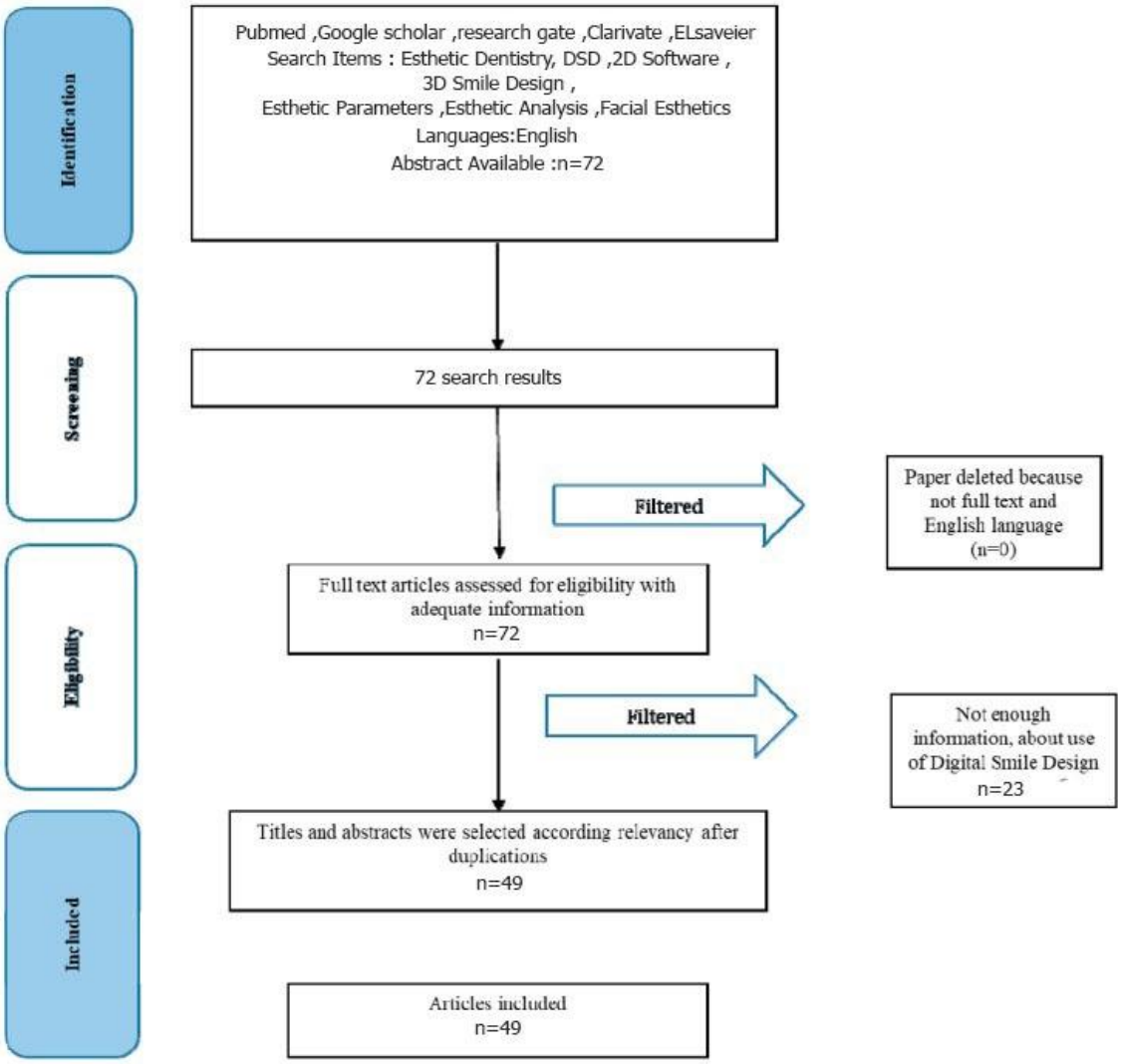

Table 2: selected studies according to the inclusion criteria

Author	Title	Study Design	Results	Outcome
Francesco Mangano ,et .al	Intraoral scanners in dentistry	Review article	This study comprised a total of 132 studies, 20 were prior literature reviews, 78 were clinical in vivo trials and 34 were comparative in vitro studies.	The optical impressions have several advantages over the conventional impression.
Doya Omar, et.al	The application of parameters for comprehensive smile esthetics by digital smile design programs	Review article	To compare the competency in an esthetic analysis of each program, 12 facial, 3 to-gingival, and 5 dental analysis parameters were selected.	The comparison of multiple DSD programs clarifies the competency of all these programs in comprehensive digital smile design.

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Christian Coachman ,et.al	Digital Smile Design: A Tool for Treatment Planning and Communication in Esthetic Dentistry	Case study	The placement of references lines and other shapes over extra- and intraoral digital photographs widen the dental team's diagnostic vision.	The Digital Smile Design is a multi-use tool that can assist the restorative team throughout treatment, improving the dental team's understanding of the esthetic issues.
Mohan Bhubaneswar	Principles of smile design	Invited review	The goal of an esthetic makeover is to develop a peaceful and stable masticatory system, where the teeth.	It is vivid from the above discussion that the smile we create should be esthetically appealing and functionally sound too.
Kazem Dalai, et.al	Maxillary Anterior Teeth Width Proportion	Literature Review	Within these articles, 4 of them talked about the absence of the Golden proportion in the study group.	A pleasant anterior Maxillary Teeth proportion is different based on teeth height, which for normal height best proportion is 70%.
Zeba Jafri,et.al	Digital Smile Design-An innovative tool in aesthetic dentistry			The digital smile design concept is a helpful tool in aesthetic visualization of the patient's problem.
Antonino Lo Giudice,et.al	The step further smile virtual planning: milled versus prototyped mock-ups for the evaluation of the designed smile	Research Article	The prototyped mock-ups showed a significant increment of the transversal measurements ($p < 0.001$)	Both prototype and milled mock-ups showed a slight dimensional increment comparing to the original 3D project.

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	characteristics			
Marta Revilla-León,et.al	Esthetic dental perception comparisons between 2D- and 3D-simulated dental dis-crepancies	Case Study	seventy percent of the dentists and 57% of the dental students preferred to incorporate the 2D simulations into their private prac-tice.	3D simulations obtained higher ratings than 2D images in dentist and dental student Populations.
Christian Coachman, et.al	Dynamic Documentation of the smile and the 2D/3D Digital Smile Design Pro-cess	Case Study		The use of dynamic smile documentation associated with the DSD protocol will make diagnosis more efficient and treatment plans more consistent.
M.Zimmermann,et.al	Virtual Smile Design Sys-tems	Review Article		In light of the new advances in CAD/ CAM technology, the poten-tial for virtual treatment planning appears feasible and promising.
CTW Meereis et.al	Digital Smile Design for Computer-assisted Esthetic Rehabilitation: Two-year Follow-up	Case study	The clinical follow-up with the intraoral aspects of the patient can be seen after six months and after two years of treatment.	The DSD is a tool that assists and allows the clinician to better predict treatment outcomes by using anal-ysis of the esthetic principles
A Zandinejad et.al	Digital Workflow for Vir-tually Designing and Milling Ceramic Lithium Disilicate Veneers:	Case report	Implementation of digital dentistry and virtual design can improve communication among the patient, clinician, and commercial dental laboratories	technology has been developed to allow digital data acquisition in conjunction with electronically transmitted data that enables the virtual design of restorations and milling at a remote production center.

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René Daher et.al	3D Digital Smile Design With a Mobile Phone and Intraoral Optical Scanner	Article review	Extraoral facial scanning using a mobile phone has emerged as a viable, cost-effective option.	This technological development is particularly promising for general practitioners (GPs) who may not be able to invest in expensive, complex digital impression devices
Mônica L. C. Aragón et.al	Validity and reliability of intraoral scanners compared to conventional gypsum models measurements	Systematic Review	Four articles were included in the qualitative synthesis.	inter-and intra-arch measurements from digital models produced from intraoral scans appeared to be reliable and accurate
Piero Rocha Zanardi et.al	The Use of the Digital Smile Design Concept as an Auxiliary Tool in Aesthetic Rehabilitation	Case Report	Not only is digital smile design an aesthetic guide protocol but its steps make the treatment phases more predictable for both patient and clinician.	The digital smile design is a practical diagnosis method that can assist the clinician to visualize and measure dentogingival discrepancies.
Fan et.al	A multidisciplinary approach to the functional and esthetic rehabilitation of dentinogenesis imperfecta type II	Case report	The diagnosis and differential diagnosis of patients with DGI-II are essential and effective in implementing a definitive treatment plan.	A multidisciplinary treatment protocol is highly effective in esthetic restoration for a patient with DGI-II.
Ron Goodlin	Photographic-assisted diagnosis and treatment planning	Article review	The advent of digital photography allows the practitioner to show the patient the photographs immediately.	This article describes recommended digital dental photographic equipment, how to produce the standard series of diagnostic dental photographs.
WS Lin et.al	Predictable Restorative Work Flow for Computer-Aided Design/ Computer-Aided Manufacture–	Case report	A digital photograph–assisted virtual esthetic plan can serve as an effective communication tool.	The approved virtual esthetic plan can be transferred to a calibrated dental laboratory along with the diagnostic casts.

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	Fabricated Ceramic Veneers Utilizing a Virtual Smile Design Principle			
Rosalia Leonardi et.al	Three-dimensional evaluation of digital casts of maxillary palatal size and morphology in patients with functional posterior crossbite	Article review	The 3D deviation analysis demonstrates a lower matching percentage of the palatal vault models in the SS (83.36%) compared with the CS (92.82%) and a location of that the palatal contraction is at the alveolar bone level.	It can be assumed that there is a bilateral symmetrical contraction of the palatal vault and an asymmetric contraction of the alveolar process
A. Lo Giudice et.al	Enhancing the diagnosis of maxillary transverse discrepancy through 3-D technology and surface-to-surface superimposition.	Case report	The aesthetics of the patient improved due to the disappearance of pre-treatment lateral mandibular deviation, with a correct centric posture of the mandible	The present diagnostic digital workflow can be a helpful user-friendly tool to analyze the morphological characteristics of the maxilla in children affected by the maxillary transverse deficiency
Francesca Cattoni et.al	Milled versus molded mock-ups based on the superimposition of 3D meshes from digital oral impressions	In vitro comparative study	The statistical analysis showed a significant difference (P > 0.01) between the mean value of the distance between the points of the overlapping STL. Meshes	: The study showed a difference in accuracy between traditional molded and milled mock-ups compared to their original wax-up.
H. T. Yau et.al	Comparison of 3-D Printing and 5-axis Milling for the Production of Dental e-models from Intra-oral Scanning	Article review	3D printing suffers from less accuracy (about 0.03–0.05 mm) but has the advantage of multiple simultaneous productions	The working models were fabricated by 5-axis machining and 3D printing and the accuracy and advantages were analyzed for both solutions.
Yoo-Geum Jeong	Accuracy evaluation of	Article review	The RMS value (152±52 μm) of	The accuracy of the 3D printing

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et.al	dental models manufactured by CAD/CAM milling method and 3D printing method		the model manufactured by the milling method was significantly higher than the RMS value (52±9 µm) of the model produced by the 3D printing method.	method is superior to that of the milling method, but at present, both methods are limited in their application as a working model for prosthesis manufacture.
Amarjit Rihal et.al	Advantages of Digital Smile Design	Case study	. Tissue response and healing were uneventful. This case was only possible given our timeline with the use of CAD/CAM dentistry and is a tremendous adjunct to our restorative practice.	Tissue response and healing were uneventful. This case was only possible given our timeline with the use of CAD/CAM dentistry and is a tremendous adjunct to our restorative practice.

Risk of Bias Across Studies

There were several limitations present in the current review. The current review includes studies written in English only, which could introduce a publication bias. There were various degrees of heterogeneity in each study design, case selection, and treatment provided among the studies.

4. Discussion

Smile is one of the most important facial functions, is often the measure of success or failure especially from the patients' point of view. [15-17] As Esthetic rehabilitation planning must be performed a thorough evaluation that includes a facial analysis, dental-facial analysis, and dental analysis.[18,19]

The dental literature recommends gathering the diagnostic data through forms and checklists[20] However, nothing indicates how the information ideally should be gathered and implemented. Therefore, many of these diagnostic data may be lost if they are not transferred in an adequate way to the rehabilitation design. The DSD protocol performed in this case allows a thorough analysis of the esthetic principles through the drawing of reference lines on digital photographs that in a predetermined sequence are transferred to a cast model and serve as a guide for diagnostic wax-ups, thereby preventing loss of diagnostic data.[21-23]

The DSD protocol allows for esthetic planning through the drawing of reference lines and the final dental design on extra- and intraoral digital photographs. That protocol widens the diagnostic vision and helps the team members measure the treatment limitations and risk factors such as asymmetries, disharmonies, and violations of esthetic principles. Also, the DSD protocol provides greater predictability of treatment and facilitates the communication between the interdisciplinary team members and the dental technician.

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Because the protocol allows for the viewing of the relationship between the preoperative situation and the ideal design, it serves as a guide to conduct the diagnostic wax-up more efficiently by focusing on developing anatomical features within the parameters provided, such as planes of reference, facial and dental midlines, recommended incisal edge position, lip dynamics, basic tooth arrangement, and the incisal plane. The protocol is also an amazing tool for communicating with patients because the clinician can clearly illustrate the issues and possible solutions, thus balancing the patients' expectations as well as increasing their understanding of the treatment plan and discussions of the prognosis. Besides, with the drawings and reference lines, it is possible to perform comparisons between the before and after pictures, which allows for a precise re-evaluation of the results obtained in every phase of treatment.[23-25]

DSD is a new tool that has been introduced to the world of cosmetic dentistry in recent years. DSD programs are used for objective esthetic analysis and virtual treatment planning by editing photographs and/or scanned models of patients. DSD technique is carried out by digital equipment already prevailing in current dental practice like a computer with one of the DSD software, a digital SLR camera, or even a smartphone.[26]

A digital intraoral scanner for digital impression, a 3D printer, and CAD/CAM are additional tools for complete digital 3D workflow. Accurate photographic documentation is essential as complete facial and dental analysis rests on preliminary photographs on which changes and designs are formulated, video documentation is required for dynamic analysis of teeth, gingiva, lips, and face during smiling, laughing and talking to integrate facially guided principles to the smile design. [27]

1. Photography protocol

To proceed with correct digital planning it is crucial to follow a photography protocol. Photographs taken should be of utmost quality and precision, with correct posture and standardized techniques, as facial reference lines like the commissural lines, lip line, and inter-pupillary line which form the basis of smile designing are established on them. Poor photography misrepresents the reference image and may lead to an improper diagnosis and planning.[28]

The following photographic views in a fixed head position are necessary:

1. Three frontal views:

- Full face with a wide smile and the teeth apart,
- Full face at rest, and
- Retracted view of the full maxillary and mandibular arch with teeth apart.

2. Two profile views:

- Side Profile at Rest
- Side Profile with a full Smile

3. A 12 O, clock view with a wide smile and incisal edge of maxillary teeth visible and resting on the lower lip.

4. An intra occlusal view of the maxillary arch from the second premolar to the second premolar.

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2. Videography protocol

According to Coachman[29] during videography best framing and zoom should be adjusted with suitable exposure and focus adjusted to mouth. For ideal development of the facially guided smile frame, four videos from specific angles should be taken:

1. A facial frontal video with retractor and without retractor smiling,

2. A facial profile video with lips at rest and wide-E smile,

3. A 12 O'clock video above the head at the most coronal angle that still allows visualization of the incisal edge,

4. An anterior occlusal video to record maxillary teeth from the second premolar to the second premolar with the palatine raphe as a straight line.

Four complimentary videos should also be taken for facial, phonetic, functional, and structural analysis. As it is, that a static photograph taken at a particular time cannot guarantee the ideal moment captured at the idealistic rest position and a real maximum full smile position, videos are helpful to allow the choice of capturing a photo at the perfect moment. Videos can be paused and transformed into a photo by making a screenshot of the best recorded moment at the desired angle. A study conducted by Tjan and Miller on static photographs of a posed smile reported that 11% of the patients presented a high smile as opposed to the 21% of patients with an anterior high smile in a study with video recording.[30] Tarantili et al. also studied the smile on video and observed that the average duration of a spontaneous smile was 500 ms, which emphasizes the difficulty of recording this moment in photographs.[31]

3- Types of DSD software

The clinician may follow any one of the given software-

1. Photoshop CS6 (Adobe Systems Incorporated),

2. Microsoft PowerPoint (Microsoft Office, Microsoft, Redmond, Washington, USA).

3. Smile Designer Pro (SDP) (Tasty Tech Ltd),

4. Aesthetic Digital Smile Design (ADSD - Dr. Valerio Bini),

5. Cerec SW 4.2 (Sirona Dental Systems Inc.),

6. Planmeca Romexis Smile Design (PRSD) (Planmeca Romexis®),

7. VisagiSMile (Web Motion LTD),

8. DSD App by Coachman (DSDApp LLC),

9. Keynote (iWork, Apple, Cupertino, California, USA)

10. Guided Positioning System (GPS)

11. DSS (EGSolution)

12. NemoDSD (3D)

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13. Exocad DentalCAD 2.3

Factors such as dentofacial aesthetic parameters, ease of use, case documentation ability, cost, time efficiency, systematic digital workflow and organization, and compatibility of the program with CAD/ CAM or other digital systems may influence the user's decision.[32] Many aesthetic parameters guide smile evaluation and design such as the midline, height, and the curve of the smile, and intra- and interdental proportion.[33-35]

It not only improves communication between clinician and patient but also between interdisciplinary team members, clinicians, clinicians, and lab technicians. All team members can access this information whenever necessary to review, change, or add components during the diagnostic and treatment phases, without being available in the same place or at the same time. This enhances visual communication, improves transparency, creates better teamwork, and interdisciplinary treatment planning. The lab technician also receives feedback on a patient's expectations related to tooth shape, arrangement, and color to enable any desired modifications. This persistent double-checking ensures the quality of the final result.

A secondary evolution of digital prosthetic planning is limited to bidimensional digital workflow and requires [36], after digital smile design protocol, the stone model, the manual processing of a laboratory diagnostic wax-up, and the printing of the classic mockup in the patient's oral cavity through the use of silicone keys. In traditional planning techniques, the data transfer from virtual design to the laboratory is difficult and potentially full of errors because it uses a manual process to obtain the computer design of canine zenith lines for the laboratory stone model.[37]

This manual process is necessary to transfer all the measurements of the teeth to the new smile project design. Another difficult and unpredictable process is the mockup printing in the patient's oral cavity with silicone mas (made on a wax-up)[.38-41]

All digital data transfer from the clinical 3D planning to the laboratory CAD/CAM process is simpler, faster, and more predictable. However, having photographs plays a crucial role: the patient-approved virtual smile is used to guide the final design of the teeth, which are usually made with the CAD/CAM process.

Conventional workflows for dental esthetic rehabilitation involves adequate communication with the dental laboratory technician by using diagnostic waxing and mock-up guide. [42-44] In this respect, it has been demonstrated that tooth preparation is more conservative when a diagnostic mock-up is used compared to the free-hand preparation.[45]

Also, diagnostic wax-up enhances the communication with the patient since it shows a realistic preview of the final aesthetic restorations as well as provides clinicians with a better understanding of the patient's aesthetic expectations.[46,47] As a consequence, patients' satisfaction with the treatment strictly depends on the consistency of the final product with the mock-up.[48,49]

However, the in-mouth mock-up molding phase is based on complex and operator-dependent procedures. This may lead to low accuracy and inconsistency with patients' expectations, in particular, if the aesthetic result has been previously evaluated and designed following patients' needs, as occurring with the virtual planning approach.[50] In this respect, virtual planning represents a useful tool to obtain esthetic in-

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formation for diagnosis and treatment plan as well as for design, fabrication, and delivery processes of the definitive restorations.[51]

The production of CAD-assisted mock-ups can be classified into milling or 3D prototyping, respectively based on material removal and additive process. Nowadays, with the progress in 3D imaging, is it possible to comparatively evaluate morphological and dimensional characteristics of anatomical structures or their reproduction. In particular, the surface-to-surface matching technique[52-55] allows the superimposition of 3D objects to evaluate the Euclidean distances between the relative surfaces; also, this digital technique provides, on a 3D color-map, the morphological differences between the superimposed structures in different colors by setting specific levels of tolerance.

The reported measurements were performed on:2D digital smile design, by referring to a specific digital caliper in 2D DSS software (Digital Smile System Srl, Italia), 3D digital smile project, by using linear measurements function in Exocad, scanned MRP and PMMA mock-ups. And, MRP and PMMA mock-ups, by using a digital caliper (Digital Caliper 0–150 mm, Mitutoyo, Japan).

The mock-up molding phase is a complex process with low reliability in specific procedures such as the positioning of the matrix, the pressuring of silicon key during resin hardening, and the resin removal.[56] A recent well-conducted study[57] found significant differences in the accuracy between molded and milled mock-ups (full digital work-flow) compared to their original wax-up. For instance, authors[58] concluded that the use of molded mock-ups would reduce the accuracy of the previewing of the final aesthetic result and that the full digital wax-up with milling technology is more reliable for the same purpose.

The main advantages of 3D printing over milling machines for the production of prosthesis manufacture are the minimum amount of material required as well as the ability to create multiple products at the same time, increasing clinical efficiency.[59,60] Prototyped mock-ups showed less dimensional changes from the original 3D project compared to the milled mock-ups as well as a better clinical adaptation. However, the present study was based on small sample size and a single milling machine, and a 3D printer, thus our findings should be taken with some caution and a definitive conclusion cannot be drawn.[61]

The majority of programs specifically for dental practice seem to overlook facial esthetic parameters and focus on dentogingival and dental esthetic parameters instead. Photoshop and Keynote were not specially created for digital smile design; however, these two programs define, measure, and modify the highest number of dentofacial esthetic parameters. The ADSD program was developed and designed to comprehensively analyze and digitally simulate a smile, while considering facial, dentogingival, and dental parameters, and can be connected to a CAD/CAM to produce a digital wax-up (Bini 2014, 2015).[62,63]

Facial analysis is performed using reference lines from which standardized parameters have been developed for frontal and profile views of the face. The dentogingival analysis includes parameters of gingival health and morphology such as the status of the interdental papillae and formation of black triangles (Patel and Chapple, 2015; Prato et al., 2004)[64,65] .the position of the gingival zenith (Magne and Belser, 2010), [66] gingival line (Pawar et al., 2011) [67], gingival contour (Camare, 2010) [68], smile line (Priya et al., 2013)[69] and the dimension of the buccal corridors (Nascimento et al., 2012).[70] .The Appropriate

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relationship of the teeth and their surrounding soft tissue will greatly determine the overall esthetic outcome of treatment.

Until now, ADSD is the only dentist specific program that includes a more comprehensive facial analysis to complement the dentogingival and dental analysis functions. CAD/CAM companies, such as Sirona have improved the esthetic features of anterior restorations in their computer software. When assessed, Cerec SW 4.2 could construct a 3-D digital model of the patient's face to allow control of all the dimensions of digitally designed restorations including functional assessment of the articulation of the models (Rihal et al.,2017)[71]

DSD programs incorporate digital technology into the smile design process and can be used as tools for diagnosis, treatment plan visualization, and communication with the patient and technician that can increase treatment outcome predictability. Other factors such as ease of use, case documentation ability, cost, time efficiency, systematic digital workflow and organization, and compatibility of the program with CAD/CAM or other digital systems may also influence the user's decision.

Photographic images are 2D projections of 3D objects; thus, objects are difficult to compare if the orientation is not practically identical.[72] This is a major limitation of the 2D–2D comparison methods. All raters reported that the 3D approach provided more information for concluding the 2D approach.

The resolution and distortion of the image may be another important limitation when attempting a photographic superimposition. A certain amount of photographic distortion is present when capturing a 3D structure in 2D. Any photograph taken without consideration could lead to angular distortion. This could be limited when the operator follows a strict protocol by using the right lens and ensure that the camera is always perpendicular (at 90 degrees) [73], which is difficult to achieve from a forensic perspective. Metric dimensional parameters have been used to assess variation in human dentition,[74,75] However, this method may not be appropriate to describe specific dental characteristics with a quantitative approach. It may be more appropriate to consider the arrangement of teeth in the arch and their relative alignment achieved with this 2D-3D superimposition method.

Limitations

This work takes into consideration the fields of use of Digital Smile Design, so it does not compare the statistical data from the individual studies. The small number of studies in the literature for this topic unfortunately represents a disadvantage.

This is a very current topic and is still not widely dealt with in the scientific field, and our study clearly explains what the fields of use are in dentistry for using this digital instrument, so it is anticipated to have good scientific confirmation. Having many scientific articles available on this topic that contain detailed information on the reliability, accuracy, and predictability of these methods, would certainly be a good starting point for further review.

5. Conclusions

It could be concluded from all the articles present in the literature regarding Digital Smile Design, that this tool provides essential information to the clinician and patient. Patients can view their rehabilitations even before they start, and this can have important medi-

co-legal functions. In recent years, these digital techniques have undergone a great positive evolution. It is also possible to remember that other techniques, such as engineering finite element analysis, have provided great support to the biomedical field, allowing for the simulation of structures even before being tested on patients, improving the quality of the rehabilitations and the predictability of the latter. Concerning planning, digital instruments appropriately interfaced with other digital files concerning radiographs and dental laboratory machines thus allow for rehabilitations that are more predictable.

Indeed, technology has been evolving in this field in recent years and will continue to include big updates on Digital Smile Design. However, facial scans would be able to make predictions of bone growth in children, to plan orthodontic–orthopedic rehabilitations, and then drive the proper growth of the jaws.

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