CURRENT PERSPECTIVES ON DIGITAL SMILE DESIGN

Luca Levrini[1a*], Silvia Croce[b], Sanda Mihaela Popescu[2c], Marian-Vladimir Constantinescu[3d]
Riccardo Botta[b], Francesca Cattoni[4e]

[1]Department of Medicine and Surgery, University of Insubria, Varese Como, Italy
[2]Dental Reabilitation and Medical Surgery Emergencies Department, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Dolj, Romania
[3]Holistic Dental & Medical Institute – ROPOSTURO, Bucharest, Romania
[4]Department of Dentistry, Vita-Salute San Raffaele University, Milano, Italy

[a]MD, PhD, Associate Professor; University of Insubria, Varese, Italy; Assistant Medical Director, Dental Clinic, Fondazione Macchi Hospital, Varese, Italy
[b]DDS, private practice
[c]DDS, PhD, Professor, Head
[d]DDS, MSc, PhD, Professor, President
[e]MD, PhD, Adjunct Professor

These authors contributed equally to this work

ABSTRACT

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Background: Digital Smile Design (DSD) is a method that helps predict digitally the outcome of a smile based on the use of both static or dynamic images, in order to plan simple or complex rehabilitation cases, to "draw a smile". It is a valuable resource used to show the outcome of the treatment, to evaluate the aesthetic rehabilitation, to complete the diagnosis and improve communication with patients, laboratories and interdisciplinary clinicians. JPEG photos and STL files are forwarded to the laboratory and imported in CAD-CAM to make a mock-up and a provisional restoration. Thus, it is possible to check each step of the planning and make any corrections necessary.
Objective: The present article is a comprehensive review on DSD, including every field in which it extends.
Data sources: The research includes articles featuring the keywords: digital smile design, prosthodontic, surgery, digital flow, orthodontics and was conducted in two different databases, PubMed and Google Scholar.
Study Selection: After screening and removing the duplicates, 22 articles from Pubmed and 11 from Google Scholar were selected.
Data extraction: The analysis included 13 articles regarding prosthetic rehabilitations, 7 articles about surgery (periodontal or rehabilitation), 11 articles describing DSD and 2 articles about orthodontics. The research included articles in English from 2000 to 2018.
Data synthesis: DSD is an excellent way to design dental treatments thanks to its versatility in managing the treatment plan; however further improvements are required to refine the software and permit an appropriate clinical application.
Keywords: digital smile design, diagnosis, communication.

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*Corresponding author:
Associate Professor Luca Levrini, DDS, PhD, President, Dental Hygiene School, Director, Research Centre Cranio Facial Disease and Medicine, University of Insubria
Via Giuseppe Piatti, 10, I-21100 Varese VA, Italy, Tel/Fax: 0332.825.663,
e-mail: luca.levrini@uninsubria.it

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Review Article

1. Introduction

In the digital era new technologies are revolutionizing the world of dentistry in order to facilitate and expedite normal procedures. Clinicians are seeking for new ways to implement more comfortable and rapid treatments yet keep high quality results. Due to the high aesthetic demand from patients, displaying a preview of the outcome is the new trend. As Coachman said, for every work of art such as painting, sculpture or dentistry, it is necessary to make a plan or a prototype[1]. Currently, there are some programs available like smile designer pro, digital smile design, aesthetic check, digital smile system to serve this purpose[2]. Digital Smile Design is among the most used, it is a software designed to make diagnostics and simulate the outcome of the future treatment: it can be seen as "outcome based workflow". Actually, for this reason the term digital smile design is considered as the main method to describe all the digital clinical works that simulate a dental treatment. The purpose of DSD is to simplify a complex task and to make sure that the patient can have a better impression of what the treatment is going to be. The virtual 2D smile design could make a diagnostic wax to facilitate clinical steps, as a computer-aided design and computer-aided manufacturing programs (CAD-CAM). Unfortunately, 3D virtual patient including intraoral soft tissue, craniofacial hard tissue and extra-oral soft tissue has some limitation, it is still complex to recreate as real[3]. Digital Smile Design (DSD) is based on the use of static and dynamic digital images, transferred to the digital software which uses different tools to "draw the smile". 2D smile design is gaining popularity as an important tool for the communication between clinicians, between clinician and patient and also between clinician and laboratory[4]. Before DSD, dental technicians used to make restoration treatments either through standard rents, photos or instructions provided by the clinician. A lot of information was missing in regards to the context in which the restoration was done, including lip

position, middle facial line, incisal plane, and some characterizations of the nearby teeth, such as colour, shape, spots or cracks. DSD can help the dental technician to make higher quality restorations and more exactly, avoid extra phases that delay the treatment. Furthermore, it is possible to re-evaluate every step of the rehabilitation, comparing it with the diagnostic plan. The use of DSD can help plan simple and complex cases with more control by the laboratory and the clinician[1]. First, digital intraoral photos against black backgrounds are needed: full smile from the front, left and right side, upper and lower occlusal view (The American Academy of Cosmetic Dentistry Photographic Accreditation Review in 1995)[5]. Second, the extra-oral photos: full smile, mid facial right and left; the patient's 3D facial soft tissues are captured with a 3D scanner (Sense, 3D system Inc). Files are then transferred as a JPEG format to the software. A diagnostic impression with an intraoral scanner in a stereolithography file format (STL) is also transferred into the software. Intraoral photos and the 2D virtual smile design are superimposed to create a virtual patient with facial tissue and a full smile.

The above mentioned are used to show the final result. The JPEG photos and STL files are then forwarded to the laboratory and subsequently imported to the CAD-CAM software to make a mock-up and a provisional restoration, even if the conversion from the 2D design to the 3D waxing could still cause distortions of the images. The definitive restoration will be created based on the test with provisional restoration and in accordance with the diagnostic plan[3].

In view of the advantages that this system has, a learning curve is required to use it to its full potential. Starting from these considerations, we decided to develop this review to analyze the most relevant literature about on the theme.

2. Methodology

A computerized database search was performed to identify relevant articles. The purpose of this work was not to aim at being a systematic review of literature, but to state the topic from the point of view of the literature analysis. The keywords introduced for the research were: Digital Smile Design, DSD, digital work flow, Digital Smile Design and Orthodontics. The databases used are PubMed and Google Scholar and the research includes works in English from 2000 to 2018. The articles were analyzed and a unique file was created for each of them with the most important information about the topic and what marks it.

3. Results

At the end of the research 33 relevant articles were found: 22 articles from Pubmed and 11 from Google Scholar. We can divide the articles selected in four groups, each one belonging to a different argument:

1. Prosthetic rehabilitations: 13 articles were about the use of digital smile design as a means to plan a prosthetic rehabilitation, like aesthetic veneers, singular crown, metal-ceramic bridges or porcelain.
2. Digital Smile Design (DSD): 11 articles were about the main theme, described the method to acquire the digital information and to develop it
3. Surgery: 7 articles were about surgery, periodontal plastic surgery, bone sculpturing, gummy smile, or implant rehabilitation
4. Orthodontics: 2 articles were found about the use of digital smile design associated to the Clin Check software of Invisalign aligners.

There are several application fields; traditionally the digital design was associated to conservative dentistry; although its use will be improved in prosthodontic, surgery and in particular in orthodontic in the future.

4. Discussion

4.1. Digital Smile Design (DSD)

Digital Smile Design (DSD) can be performed with Key Note (for Macintosh) and Power Point (for windows). Through DSD, pre-existing dental anomalies such as shape, size, position, color or texture can be identified and modified with the ultimate goal of designing the optimal smile[6]. It starts with data gathering and digital planning. On the full face extra-oral photo horizontal and sagittal plane are tracked in accordance with anatomical references: inter-pupillary line and middle facial line (glabella-nose-chin).

These lines are transferred to the full smile intraoral photo for a comparison with the occlusal plane and the dental midline.

The second step is the dental analysis (horizontal lines): the outline of each tooth is drawn and enclosed in a rectangular, combined with the future treatment, the tip of each canine, the incisal edge of both central incisor and dental midline. The ideal proportions of length and width are placed to be compared with the project, including measurements in millimeters to calibrate the size of each element. Finally, the smile design is superimposed on the initial situation to show the relation with the gingival contour, and then the virtual waxing is performed[7,17]. A digital ruler is used to show the measurement of the teeth.

After having investigated the patient's expectations, the treatment proposals are exposed; the patient approves the design and chooses which treatment plan to proceed with and subsequently the clinicians decide the operative time table. In the traditional DSD protocol the digital wax-up is transferred to the master cast, maintaining the tooth's design, and it is used to fabricate the silicone guide for the provisional denture[8]. It is important to have a check list to follow in each step; there is a constant double-check between the DSD and every phase of the treatment to identify and correct any errors and give a higher quality to the treatment.[9]

If patients are not satisfied with the result of an aesthetic rehabilitation the clinician can change something about the design and can adapt the functionality. Thanks to the DSD clinicians can reach the patient's compliance and patients have no surprise at the end

of the treatment thanks to the pre-visualization of the outcome[10].

4.2. DSD in Prosthodontics

In recent years the expectations of dental patients have greatly increased regarding their aesthetic appearance, which has already reached the same importance as the function[11,12]. To pursue the least invasiveness is a priority in every prosthetic restoration which aims to improve the smile aesthetics, preserving as much dental tissue as possible and respecting the surrounding soft tissue[13]. As demonstrated by Magne et al, a veneer preparation approach driven by the final volume of the restoration (the mock-up) allows for more enamel preservation, avoiding unnecessary overpreparations by removing just the dental tissue needed to create proper prosthetic thicknesses, and more predictable bonding, biomechanics and final aesthetics[14]. According to Coachman's protocol, the realization of the diagnostic wax-up is anticipated and, above all, guided by the Digital Smile Design, which has proved to be a fundamental and useful tool for improving communication and the patient's acceptance, but all the remaining steps are the same as the traditional ones[15]. The DSD used for planning a prosthetic rehabilitation is probably the most common application of the software, as it also emerged from our literature review. It allows to design treatments without needing the patient to sit on a chair and analyze the treatment plan in this way, by considering all the aesthetic parameters[16].

The key to the success of the treatment is the harmony between the various components of the smile's aesthetics, such as colour, shape, volume, texture, dental alignment, gingival contour, the relationship between the teeth of the upper arch and those of the lower arch as well as the contextualization in the face[17].

The starting point is always drawing the references lines extra and intraorally: the reference planes are drawn (bipupillary line, middle facial line, Frankfurt plane), dental middle line, occlusal plane, tooth contour. When parameters are provided we proceed with designing the diagnostic wax-up, referring to the anatomical features, the lip dynamics, the incisal edge position and midlines[18]. With the DSD software it is possible to design different types of prosthetic rehabilitation such as porcelain laminates veneers, ceramic crown or bridges[19]. The most common are aesthetic veneers, both of feldspathic ceramic, lithium disilicate and zirconium. In order to perform an aesthetic rehabilitation with veneers/dental crown a silicone index is obtained from the dental cast to evaluate the need for reduction and another silicone guide is for the provisional restorations[20]. The creation of an interim prosthesis allows us to visualize possible errors in the design and thus be able to make changes to the final prostheses; additionally, it is also serves as a further pre-visualization of the patient, even though he can already see the result thanks to the DSD software[21]. Often the aesthetics of the smile can be improved without resorting to a prosthetic treatment but preferring a more conservative treatment such as dental bleaching or the application of infiltrative resins or aesthetic reconstructions in composite[22]. In cases of morphology changes (microdontics, conical teeth) or colour (dyschromia, tinctures, dark non-vital teeth) and structure (enamel deficiency as hypoplasia, white spot) this is not possible and the prosthetic option remains the best choice[17,23].

While in the traditional DSD protocol the digital wax-up is transferred to the master cast, maintaining the tooth design, and it is used to fabricate the silicone guide for provisional denture[8], in recent months an evolution of smile design protocols has been achieved and a project using only digital methods has been executed called Digital Smile Planning[24].

In this case the design of the patient's restoration was then performed using the DSS-2D software (3D Lynx-, 3D Lynx srl, Italy).

The software allows designing digital aesthetic and functional smile rehabilitation through a guided path, and which, thanks to the automatic calibration tools, can perform mathematically controlled measurements. This program allows the patient to preview the prosthetic result directly on a photograph of himself and provide the dental technician with all the information needed to perform the work through a detailed report[24]. The digital restoration project was realized using the patient's photos, and choosing dental shapes from the software libraries. The use of a specific landmark while taking the patient's photographs, with reference points, allows the software to calibrate the system on the picture so that it can give precise measurements in millimeters, useful to guide the work of the clinician and, above all, the technician. It is also necessary to take an intra oral optical impression to feed the original shape of the natural elements into the CAD software. The STL files of the patient's arches have been uploaded to the software for the realization of the digital wax-ups by the DSS-3D system (CAD Lynx-, 3D Lynx srl, Italy), direct implementation of the DSS-2D system, and a milled mock up has been produced and tested in the mouth of the patient, to guide the tooth preparation and, if necessary, also the surgical evaluation of the soft tissue design.

Nowadays it is also possible to apply the digital planning protocol not only on natural teeth, in simple or complex cases, but also in the initial phase of the full-arch implant supported rehabilitation protocol[25]. The Virtual Implant-Prosthetic Procedure: VIPP Technique[25], can be used to integrate the prosthetic and the implant project helps the correct guided implant positioning[26], optimized either for bone volumes available and to absorb the masticatory loads and the fabrication of an adequate prosthesis, in compliance with the intermaxillary relationship, the function and the occlusal balance, the soft tissue support[27].

4.3. DSD in Surgery

Digital smile design has also found its usefulness in the surgical field. The digital workflow in the surgical area begins with the collection of radiographic data

and then the photos. It is possible to superimpose on the CBCT the DICOMs files (Digital Imaging and Communications in Medicine) for planning the surgery. Unfortunately, the combination of several files can create image distortion and diagnostic dental models are needed to overcome this problem[2]. An analysis of the distance between the margin of the future prosthetic rehabilitation and the existing bone is necessary to determine if a grafting procedure will be required, if implants can be placed at the level of the bone, or if bone reduction is needed and if the future restoration needs to incorporate a pink prosthetic area. Some guidelines using the margin of the planned crown as a reference can be applied. Implants must be placed 3 mm apically from the margin of the planned crowns to create space for average biological width thickness[28]. Regarding the orthognathic surgery, a sagittal analysis with cephalometric guide is essential to place the maxillary central incisor in the best position and in harmony with the lips and face[28].

A combination between periodontal surgery and prosthetic rehabilitation is possible to carry out in case of a gummy smile. A preliminary study is essential to make the diagnosis: once the treatment has been established, if a bone or gingival reduction is necessary, digital planning of the mock up and the surgery is performed. The surgery is guided by a splint made according to the digital design so that the gum is in the correct position for the future prosthesis. The provisional made on the basis of the planning is used as a surgical stent[23,27]. In many cases it is not possible to correct a gummy smile only with a gingival reduction; often an orthognathic surgery or orthodontic treatment is required. Thanks to the digital smile design the patient can see the outcome and decide whether to accept the aesthetic compromise in case he does not want to undertake a more invasive treatment[29].

4.4. DSD in Orthodontics

Nowadays, modern orthodontic techniques (clear aligner) allow early visualizations of the orthodontic treatment that is necessary to proceed further with the production of aligners. In the perspective of considering DSD as a digital visualization of the result that could be obtained, this early visualization already guarantees an excellent projection of the result.

However, these simulations do not permit to predict how the results of an orthodontic treatment can be compared to the patient's mini-aesthetics (smile with the lips) and macro-aesthetic (face): the available digital models of orthodontic treatment, in fact, are substantially 3D-image digital devices that simulate only the patient's dentition.

For this reason, digital methods have been developed in a way which permitted to combine the views of orthodontic treatment with images of the patient's face: the result was an image that represented the patient's smiling face with the simulation of the teeth as it would appear after the changes at the micro- and macro-aesthetic level obtained thanks to the orthodontic treatment. These digital methods are generally performed with professional photo processing software (photo editing), such as Adobe Photoshop®.

For this aim it may be sufficient: -to make a digital transparent model that simulates the result of orthodontic treatment of the patient's dentition; - to position, overlap and manually align the transparent digital model onto an image of the smile or face of the patient with his original teeth and gingiva. This photo must be taken with the patient's occlusal plane in a perpendicular position to the lens, with the teeth in front view compared to the camera; - erase the original teeth and gingiva from the image of the smile or face, in order to obtain an image of the face without teeth but with a residual of the original gum on the transparent digital model; - bring the transparent digital model below the smile image or face without teeth and with a residual gum;- eliminate the transparency from the digital model, obtaining an image of the smile or face, which integrates the orthodontic simulation of the digital outcome;- change the color of the gums and the teeth to simulate a natural effect of the patient's gums and teeth.

Actually, this method can be called "orthodontic digital face design"; practically, an image of the patient's face or smile is produced and is integrated with the occlusal result of the orthodontic treatment. In this way, the patient is able to appreciate the simulation of the orthodontic outcome which he is undergoing or must undergo before starting and appreciate the aesthetic of his smile or face. It is possible to add restorative rehabilitation, either prosthetic or conservative. The method could also include a patient's three-dimensional (3D) image of the smile or the face[22].

Schabel et al. published a study that compares the accuracy between photographs and video clips regarding the possible distortion of the image in a sample of patients treated orthodontically. The results showed that there was no significant difference between obtaining images using traditional photographic method or extrapolating them from video. Yet, a slight difference of 1mm was seen when analyzing the upper incisor in relation to the lower lip. Therefore, photography is still considered the best tool and the most immediate tool[5].

5. Conclusion

The appearance of a beautiful smile is impregnable, because the mouth is the most important manifestation of a human being. The DSD protocol, consisting in drawing reference lines on extra and intra-oral photos and superimposing the dental design, is an excellent tool for a diagnostic vision and help the team members to predict and facilitate the treatment[31]. It reduces the risk of asymmetries, disharmonies, guided by the diagnostic wax based on aesthetic principles. It works both with macro aesthetic (face and neck), mini aesthetic (the smile and the lips) and micro aesthetic (details about the shape, the color and defects of the teeth). The purpose of DSD is to guide every step of the treatment by focusing on anatomical features,

parameters provided, and planes of references, each of them conducted by the wax-up design[33]. Among the advantages of this software one can list: reduction in the number of appointments, low clinical costs and a global access to the service as it allows the clinical staff to visualize the relevant data and transfer other information via Internet. Lot of diagnostic data are stored in a single software which allows sending all of them to the laboratory without the need of explaining the procedures[33]. DSD facilitate the interdisciplinary communication between dental technicians and the operator. The DSD is also useful to pre-visualize the outcome of the treatment to the patient and improve the communication with them by illustrating clearly the situation before and after[35]. It is a simple technique, it does not require specific equipment; however, a handling training is firmly needed. Nothing indicates how the information should be ideally 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 consists in transferring data to a cast model that reproduces the wax-up diagnostic in such a way as not to lose the information (of the photos) [17]. In conclusion to this review it can be said that the digital smile design is an excellent tool for treatment planning, especially for aesthetic treatments, as it is more used and to design prosthetic rehabilitations in the anterior sector[36]. However, there are still uncertainties regarding the occlusion adjustment: in fact, errors can be found during the transfer of data from the scan to the realization of the study models. This could be the biggest disadvantage of the program. The chances of not reaching a correct occlusion emphasize the importance of the temporary restoration to recheck and correct any errors. For this reason, the technique requires a learning time to be able to take full advantage of its usefulness.

The topic is mainly addressed for the clinical application, for this reason there is not significant literature evidence; the idea could be to create a panel of experts in the fields to edit the clinical guidelines on the DSD.

Author contributions

LL: Idea, study concept and preparation of manuscript. SC: literature search and analysis orthodontic topic. SMP: Contributed to re-writing manuscript. MVC: Revision of manuscript and literature search. RB: literature search and analysis surgery topic.
FC: literature search and analysis prosthodontics topic

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Luca LEVRINI
DDS, PhD, Associate Professor
Deputy President, Dental Hygiene School
University of Insubria, Varese, Italy
Assistant Medical Director
Dental Clinic Fondazione Macchi Hospital, Varese, Italy
President Fondazione Alessandro Volta, Como, Italy

CV

Professor Luca Levrini, born in 1967. Associate Professor in Clinical Somatology and deputy president Dental Hygiene School, University of Insubria, Italy. Assistant Medical Director, Dental Department, Fondazione Macchi Hospital, Varese. Member of the Medical Council, Como, Italy. Medical Journalist. President Fondazione Alessandro Volta, Como, Italy. Author of more than 200 scientific papers dealing with oral prevention and orthodontics. He is an active member of Società Italiana di Ortodonzia and a Certificate speaker for Align Technology.

Questions

1. Which information is transmitted to lab through classical recordings?

❑a.Lip position;
❑b.Middle facial line;
❑c.Incisal plane;
❑d.Tooth position.

2. Which is the limitation of DSD?

❑a.Simplifying a complex task and making sure that the patient can have a better impression of what is going to be the treatment;
❑b. Making a diagnostic wax;
❑c. Facilitating clinical steps, as a computer-aided design and computer-aided manufacturing programs (CAD-CAM);
❑d. Too complex to recreate as real.

3. Digital Smile Design (DSD) can be performed with computer programs like:

❑a.Key Note (for Macintosh);
❑b. Excel (for windows);
❑c. Word (for windows);
❑d. Paint (for windows).

4. With the DSD software it is possible to design different types of prosthetic rehabilitation. Which are the most common?

❑a.Aesthetic veneers;
❑b. Crown;
❑c. Bridge;
❑d. Denture.