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The current use and effectiveness of Digital Smile Design in contemporary dentistry – A Systematic Review

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Abbreviations

DSD: Digital Smile Design

DSS: Digital Smile System

DP: Digital Photography

MCI: Maxillary Central Incisors

MLI: Maxillary Lateral Incisors

mm: Millimeters

IOS: Intraoral Scanner

AI: Artificial Intelligence

CBCT: Cone-Beam Computerized Tomography

CAD-CAM: Computerized-Aided Design/Computerized-Aided Manufacturing

2D: Two-dimensional

3D: Three-dimensional

RCT: Randomized Controlled Trial

VAS: Visual-Analogue Scale

VRS: Visual-Rating Scale

NOS: Newcastle–Ottawa Scale

Abstract

Introduction: Digital Smile Design is a new tool in esthetic dentistry with the purpose of facilitating previsualization of the treatment outcome and to improve communication between dentist, technician, and patient. To perform DSD knowledge of dental aesthetic guidelines is vital.

Objectives: The aim of this systematic review is to analyze present DSD methods, dental treatment planning software and digital dental photography, to show their benefits and advances and to assess the degree of patient satisfaction in treatment planning with DSD.

Materials and Methods: A comprehensive literature search was conducted in the online data bases PubMed, Medline, Cochrane, and Scopus to search for articles with scientific relevance indexed about the applications of digital smile analysis in dentistry. Inclusion criteria where publication within 2012 and 2022, DSD with any type of software, RCTs and non-randomized clinical trials, Observational studies and Case Series studying the effect of DSD and English, Spanish, or German language. Exclusion criteria patients with specific diseases, immunologic disorders or other oral risk-related systemic conditions or craniofacial discrepancies, studies with a conflict of interest or focusing on other technologies not related to digital dentistry or do not provide enough information regarding the selected topic
The search was guided by the specific objectives, and it was performed using the words ´aesthetic dentistry´, ´smile aesthetics´, ´digital smile analysis´, ´digital dentistry´, ´smile`, ´digital smile design`, `DSD´ and ´dental photography`. For Bias Assessment, the NOS and Cochrane Collaboration tool was applied.

Results: A total of 13 studies regarding the use of DSD in dentistry were chosen based on the inclusion criteria. A total of 689 subjects were analyzed. The results demonstrated that nowadays DSD is used interdisciplinary in dentistry and that it improves communication, treatment predictability and patient satisfaction.

Conclusion: The amount of literature of DSD is still limited since it is a quite new advance in dentistry. However, the included studies confirmed that the trend of DSD in dentistry is rising which lays the foundation for a digital future in contemporary dentistry.

Keywords

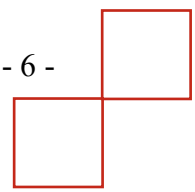
Digital Smile Design

Digital Smile Analysis

Digital Dentistry

Dental Photography

Esthetic Dentistry



1. Introduction

1.1 Aesthetic Dentistry

During the last years, the demands in dentistry are shifting from a mostly functional idea to a more holistic approach where aesthetics play a leading role for both patients and dentists. Even when pain or discomfort is the motive for a consultation with the dentist, patients ask nowadays for a treatment that is aesthetical and cost-effective. The branch of dentistry which combines all these ideas into a treatment plan is called Aesthetic dentistry.

Unlike for example orthodontics, prosthodontics or restorative dentistry, aesthetic dentistry is not considered as a special field in dentistry, though along with functional and biological considerations, it is one of the main goals which most dental treatment interventions have in common. Aesthetic dentistry embraces nearly all well-known and accepted specialty areas nowadays, starting from preventive and restorative dentistry to prosthodontics, orthodontics, periodontics, as well as oral and maxillofacial surgery (1)(2). Through a medical and dental anamnesis, clinical examination and its accompaniment with photographs and study models, the dentist can come up with a suitable diagnosis and treatment plan, however, all these steps still lack parameters that analyze the patient's smile from an aesthetic point of view (3)(4). Moreover, it should be a common step in the treatment plan to determine the relationship between the face, lips, teeth, and gingiva when evaluating them from a functional point of view to let them influence the treatment outcome (5). The main goal in dental smile design is to imitate teeth and design natural and pleasing smiles by respecting the individual and specific needs of the patient and improve proficiency of the cosmetic dental treatment (1)(6). To analyze such a huge number of variables, several types of analyses have been established. The fundamental goal of all of them is to provide metrics and references that may be used as guidance for the proper alignment of the maxillary anterior teeth. Clinicians should be able to identify objective and basic modes of evaluation despite the abundance of concepts and analyses accessible (7). The different approaches to achieve this goal have been significantly improved over the last years by employing new treatment methods, more

functional and aesthetic dental materials, and novel techniques and technologies (1).

1.2 Aesthetic Guidelines

It has already been discovered in the late 19th century that respecting and understanding the natural tooth arrangements, positions, proportions, shapes, color, and morphologies is the basis for a good treatment outcome. Today, these parameters still mark the foundation of aesthetic dentistry and should be respected in all individual cases (1). However, rather than scientific investigations and sensations, observations are frequently resulting in very subjective and individual perceptions that are being codified further into universal aesthetic norms and principles (8). The first parameter in a dental aesthetic evaluation is frequently the correlation between the dental and facial midlines (1)(9). Traditionally, dental, and facial aesthetics are defined in terms of macro and micro aesthetics. The link between the face, lips, gums, and teeth, as well as the idea that these relationships are appealing, is referred to as macro aesthetics. Micro aesthetics entail the aesthetics of a single tooth, as well as the perceptions induced by color and form (4).

1.2.1 Facial Harmony

It has been demonstrated that there is strong scientific support that the impression of a person's face and teeth has a recondite influence on perception and judgments by others. The eyes and the mouth of the human face play a key role in the perception and the aesthetic impact of the face. Over the past 130 years, authors are manifesting in various works that symmetrical patterns are in principle more attractive to people than asymmetrical ones. The degree of facial symmetry is supposed to convey the degree of phenotypic and genotypic quality, in other words, the more symmetrical a person is, the more attractive he or she will be perceived by others (5)(8). The structure and movement of the teeth and lips reveal a variety of emotions, and the smile is used to assess how well a person performs in society (10). It is important to underline that there is

no single ideal facial aesthetic. A facial appearance considered highly aesthetic by some individuals may be considered less aesthetic by others (11). Further, it is confirmed that a harmonizing facial appearance and a pleasant smile is associated with kindness, popularity, intelligence, and high social status (1)(5). It is even more remarkable that the degree of self-satisfaction with the own smile is directly correlated with self-perception and positive psychological attributes, nevertheless, an unpleasant smile is associated with neuroticism and thus directly affects the own well-being and health negatively (1)(12). Although there is great scientific evidence on the importance of a harmonious facial appearance and a nice smile, the actual need for aesthetic or cosmetic dental treatment is always being discussed controversially because of ethical concerns and the fact that too invasive and unnecessary or unsuccessful treatment can have a severe outcome on the well-being and overall appeal of the patient (1). The key consideration in aesthetic dentistry is that each person's smile, aesthetic needs, and perception of harmony and beauty are all unique (6). Perception has a psychological component, and there is a well-documented conflict between the patients and the dental professional's judgments on dental aesthetics (1)(4).

1.2.2 Golden Ratio

One of the most important aspects has become the creation of geometric or mathematical proportions to relate to the desired esthetic width of the anterior teeth in dentistry (10). The dimensions of the smile might be based on proportions and parameters such as the so-called golden ratio or "divine proportion" (*Divina proportione*), which was manifested by Leonardo da Vinci in the late 15th century (5). The Golden ratio, which is a continuous ratio of 1: 1.618, is one of the most important and beneficial principles in esthetic dentistry (13). It is being demonstrated to be appealing to the human eye and is an often-noticed phenomena in nature. With the first introduction in esthetic and restorative dentistry, it advocates that the apparent dimensions of the maxillary anterior teeth can be approximated when observing from the a frontal view (13). When applying golden proportions to a dental smile analysis, this implies that when starting at the midline, the width of each consecutive tooth decreases in the same

proportion as it progresses distally. From a frontal view, the ratio between the width of the MLI and MCI should be 1: 1.618, while the optimal ratio between the width of the MLI and the canine would be 1: 0.618. As a result in percent, the lateral incisor should be 62 percent of the central incisor's width, and the canine should be 62 percent of the lateral incisor's width (14).

1.3. Dentolabial Analysis

The evaluation of facial, dentolabial, and phonetic characteristics, as well as the analysis of facial features and lip motions in connection to the teeth, is an essential stage in esthetic dental smile design (15). Dentists must plan the esthetic treatment with two fixed dynamics in mind. The first dynamic is the examination of soft tissue at rest and during movement, and the second is the patient's aesthetic changes over time when ageing (4)(16). The position of the eyes, nose, lips, and chin, as well as the frontal and lateral analysis of the patient's face, allow us to determine important vertical and horizontal reference lines and points for esthetic rehabilitation (6). According to traditional principles, the esthetic aspect of the face is divided into equal thirds, being the frontal, nasal and lower third. Subsequently, the lower portion of the face is the focus of the dentolabial analysis (9). During speaking and smiling, the face and lips constitute a dynamic framing for the teeth, with tooth exposure continually changing (12)(15). The relationship between the lip and the tooth varies with time, with the extent of maxillary incisor exposure decreasing (16). The parameters which should be assessed during the dentolabial analysis are the incisal edge position, the tooth exposure at rest, the smile lines, buccal corridors, and the dental and facial midline, and the occlusal plane and commissural line (1).

1.3.1 Incisal Edge Position and Exposure at Rest

The front teeth have a significant impact in the appearance of the face (17). The apicocoronally (incisal curve) and anteroposterior (incisal profile) positions of the incisal edge must be determined in both apicocoronally and anteroposterior directions (15). While seen from the front, the incisal crest

should have a convex curve that follows the natural concavity of the lower lip when smiling. Its position has a considerable impact on many of the clinician's and dental technician's restorative procedures (12)(15).

Between the age of 30 and 60, the maxillary central incisor is said to shrink by around 3.4mm. Gingival display during a smile, on the other hand, reduced with age in both men and women. However, the length of the upper lip and the height of the lip commissures increase with age, especially in men (16). They also see a considerable decline in the exhibition of the MCI at rest, speech, and smile as they age. In both genders, there is an increased display of the mandibular incisors with age is a common occurrence (10). Gingival exposure when smiling is seen as a juvenile and feminine trait. Moreover, it is possible to distinguish between males and women's aging processes in soft tissue and incisor display starting at the age of 25 (18). Abrasion of the incisal margins can sometimes result in a flat or even reverse incisal curve, which can be unappealing from an aesthetic standpoint. The mismatch between the incisal plane and the curve of the lower lip creates a negative anterior space, and the interincisal angles, which are a crucial element in the first appearance of the smile, are reduced or eliminated in some circumstances (15). When the jaw is relaxed, the position of the incisal margins of the central incisors is the most essential criterion in cosmetic denture setups and smile designs (1)(16).

1.3.2 Anterior Overjet and Overbite

An overjet is defined by the distance measured in a direction parallel to the occlusal plane between the buccal face of the lower incisor and the incisal edge of the MCI. Ideally, it should be a distance between 1 and 2 millimeters (mm). It is a positive or increased overjet when the distance between the maxillary and mandibular incisors is larger than 3 mm. When their projection is between 0 and 2 mm, this is called edge-to-edge bite. When measured at less than 0 mm the overjet is considered to be negative (16)(19). The definition of the term *overbite* is the vertical distance between the incisal edges of the upper and lower central incisors. Usually, it is between 2 or 3 mm or it can also be expressed in thirds, one third being the normal amount (15). Any values exceeding 3mm or

more than one third are considered as a malocclusion in Orthodontics and as unesthetic in Aesthetic dentistry (12)(16).

1.3.3 Dental Smile Lines

In total there are six different horizontal smile lines determined, being the upper lip line, the cervical or gingival line, the papillary line, the line of contact points, the incisal line and the lower lip line (7). A useful guide for the evaluation of the upper lip line was established by Tijan et al. in 1984 (20). Smile types were analyzed by the height of the upper smile line, which is the amount of dental structure being displayed when a person is smiling. Following that classification, an average smile shows between 70% to 100% of the maxillary anterior teeth, premolars, and interproximal papillae tips in this categorization. A "high" smile line is defined by the more gingival show, whereas a "low" smile or lip line is defined by a fewer teeth display (1). The definition of a low smile line is a visibility up to 75% of the anterior superior teeth. A medium height smile line is marked by an exposure between 75 to 100% of the upper anterior teeth including the interdental papilla (7). The high smile lined is established at an exposure of 100% of the anterior superior teeth including a large amount of the gingiva situated above the teeth (7)(9). An attractive smile is said to be characterized by the situation that the upper anterior teeth are completely visible and that at least 1mm of the upper gum tissue is exposed (9). In cases where a maximum of 2 to 3mm of the gum tissue is exposed, there is still no aesthetic impairment. If these values are exceeded the smile is considered as less attractive by most patients (18) (20). Another factor affecting the smile line and the overall smile appearance would be the incisal wear. Even though they are more common in adult patients, wear of the margins of maxillary anterior teeth can be diagnosed at any age. (16) Occlusal wear alters the design of incisal lines, and thus the perception of the smile, in addition to modifying the size and esthetic proportions of teeth (12). From a frontal view, the incisal line follows a convex shape parallel to the lower lip line which form into a natural concavity when smiling. This phenomenon is observable in an estimated 75% of the cases and is correlated to the individual facial pattern

(12). It is said that a pleasing smile is characterized by the incisal line running against the upper portion of the lower lip line while the upper lip line presents and upward curvature (21). The distance between the base of the nose and the bottom border of the upper lip (nasolabial fold) was measured by Peck et al. who found average values of 20 to 22 mm in women and 22 to 24 mm in men (1)(15). The smile line in women is 1.5 mm higher than in men due to the decreased height of the upper lip (1). This also explains why women have a higher rate of elevated smile lines independently from the smile height, the center of the upper lip may adopt a convex, plane, or concave structure when elevating. For this reason, depending on the length of the upper lip, this factor also influences the exposure of the MCI (16)(17). The upper lip, like the lower lip, can change during aging. As a result, it is an unreliable unit of measurement. In turn, regardless of the curvature of the upper lip, the course of the incisal edge, as in the case of the lower lip, should adapt to the horizontal reference plane, the interpupillary line (18). When more than 3 to 4 mm of gingiva is visible above the dental crowns when smiling, it is referred to as a *gummy smile*, which many patients find rather unappealing, resulting in a common chief complaint for aesthetic dental treatment (22)(23).

1.3.4 Buccal Corridors

When smiling, the upper anterior dental arch is normally visible. The premolars and, in some cases, the first molars can also be observed (5). The term buccal corridor refers to the black areas between the buccal surfaces of the top posterior dental arch and the corners of the mouth. These gaps are another sign of a natural smile line that is balanced. The continual decrease in light reflection in the area of the posterior teeth, as well as the decreasing coronary lengths from front to back, intensify this perspective illusion (1). It can be concluded that the buccal corridor is a negative gap that appears as a black or dark space between the lateral sides of the maxillary posterior teeth and the corner of the mouth during smiling. Buccal corridors create the impression of a normal dentition, but their absence give the patient an unnatural appearance (12). Since the mouth widens by up to 30% when smiling, an excessive

transverse lip extension occurs which will subsequently result in a more ample buccal corridor (24).

1.3.5 Facial and Dental Midline

It is vital to assess the face composition before concentrating on the teeth (8). The identification of reference points and lines that are essential for orienting the occlusal plane and the gingival outline in esthetic rehabilitation can be accomplished by performing a frontal and lateral examination of the subject, which includes an analysis of the position of the eyes, nose, chin, and lips (3). The facial and dental midline play an important role in facial esthetics, cosmetic dentistry, facial plastic surgery, and anthropologic studies (8). Their correlation is in many cases the first parameter to evaluate during esthetic treatment planning (1). The glabella, nostril, upper lip philtrum, and chin extremity should all be perpendicular to the interpupillary line, separating the face into two parts, one of which should be an ideally symmetric reflection of the other. The maxillary interincisal line is the most ideal reference for determining the dental midline (14). However, because every mesiodistal inclination of incisors can easily cause changes in the characteristic, the gingival papilla between the two MCI is the optimal choice as a reference for the determination of the dental and facial midline (15). These two midlines should coincide in a beautiful smile, but in nature, misalignment is rather more common. Consequently, the wider the distance between them, the greater the facial asymmetry (25)(11).

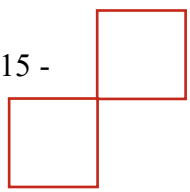
1.3.6 Occlusal Plane and Commissural Line

The incisal tips of the MLI should be about 1 to 1.5 mm superior to the occlusal plane in an attractive smile, with the MCI and canines positioned nearly at the same incisal height with one another (11). When setting the smile, location, and angulation of the occlusal plane, the dentist must take these factors into account. The interpupillary line is frequently utilized because of its ease of usage since it's simple to locate and generally constant in most persons. (8)

Furthermore, it also gives a precise image of the inclination of the occlusal plane (26).

1.4 Digital Workflow in Dentistry

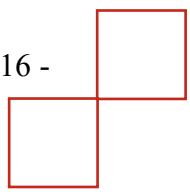
The invention of integrated techniques that provide tailored treatments for patients will be the future of digital dentistry (27). Since its creation, Artificial Intelligence (AI) is introducing significant improvements that are revolutionizing our daily lives and activities in a variety of ways. Although advances in the field of AI may not appear to have a significant impact on esthetic dentistry in the first place, certain areas, such as image-based automatic detection, intraoral digital impression techniques, and the resolution augmentation of dentistry related images, are seeing major benefits (25)(27). Furthermore, developments in digital esthetic dentistry enhance the workflow by allowing the development of models that enable a thorough characterization of tooth color, improving the effectiveness of esthetic dental restorations (2)(27). Appropriate diagnosis and treatment planning procedures are critical to the success of esthetic restorative dentistry. Digital technology such as intraoral and facial scanners, as well as computer-aided design (CAD) software packages, enable the incorporation of digitally recorded patient data and the creation of a digital portrayal of a patient (28). Considering the advancements in esthetics dentistry, the traditional steps in workflows that were once considered standard, such as obtaining alginate impressions, treatment planning and template design on gypsum-based models and relying on two-dimensional (2D) images of 3D dentomaxillofacial structures, are constantly being overtaken by more effective and precise digital approaches (2). For each dental specialty, the digital workflow process follows a particular set of procedures (22). The imaging chain, on the other hand, is the essential element in the diagnosis, treatment planning, and workflow (29). All or at least some of the following modalities are frequently included in the imaging chain: Digital Photography (DP), Acquisition of cone-beam computed tomographic (CBCT) data, segmentation of the CBCT image, intraoral scanning (IOS), capture of facial 3D soft tissue, and superimposition of all images to create a virtual augmented model (30). A collaborative approach is even more vital for digital processing



because it affects the dentist, the dental assistant, and the technician equally (20). It's critical to be aware of the boundaries that exist within the imaging chain in order to build an effective digital workflow (22)(30). Moreover, in the future, techniques based on AI may need to be integrated to make the workflow even more simple, precise, and quick (27). DSD can be performed, allowing the patient to have a better understanding of the expected treatment outcomes before starting a treatment plan (7). DSD is accomplished with digital equipment that is already in use in today's dentistry practice, including a computer with DSD software, a digital camera, or even a smartphone. Additional instruments for a complete digital 3D workflow include a digital oral scanner, a 3D printer, and CAD/CAM. It is vital to perform a correct DP process in order to obtain a satisfactory Smile Design (31)

1.4.1 Digital Smile Design

Assessing, diagnosing, and restoring esthetic flaws requires a well-informed, planned, and disciplined approach. In order to achieve a natural and pleasant smile, the esthetic aspects should be drawn into a compelling smile design (5). The assessment of ideal proportions of dental width and height, along with the positioning of the long axis of teeth (angles and inclinations) and the relationship between the colors, being white (teeth), pink (gingiva), and black (buccal corridors and black triangles), are all covered by DSD (7)(22). The color naming or color designation approach is one area with significant use in esthetic dentistry (27) The most common way of determining dental color is visual color matching, and most esthetic dental products employ VITA shade designations. Color evaluation and color standard in dentistry, on the other hand, meet two major challenges: First of all, human color perception is subjective and various manufacturers provide material colors that differ from the original (27)(32). In order to analyze the patient's smile in a correct manner intraoral optical scanner (IOS) are used (7)(30). IOS allow the precise production of digital impressions, which replaces the need for conventional dental impressions.



Recent investigations have shown that digital impressions can achieve great levels of accuracy and authenticity. (27)(33) Nowadays, among the most common DSD programs described in the present literature, we can find Photoshop CS6 (Adobe Systems Incorporated), Keynote (Apple Inc.), Smile Designer Pro (SDP, Tasty Tech Ltd.)), Aesthetic Digital Smile Design (ADSD – Dr. Valerio Brini), Cerec SW 4.2 (Sirona Dental Systems Inc.), the DSD App by Coachmann (DSDAPP LLC), Planmeca Romexis Smile Design (PRSD) (Planmeca Romexis), Smilecloud Biometrics (Florin Cofar) and Smile Creator (Exocad) (28)(31)(34). DP, imaging and design allows the patient to previsualize the anticipated outcome before the treatment is initiated, increasing the treatment's predictability and patients satisfaction (6.) DSD is also a very powerful marketing tool (29). Consequently, it can be said that digital smile design (DSD) in aesthetic dentistry is not only based on the patient's needs and wishes, but also on the individual capacity of the clinician and dental technician.

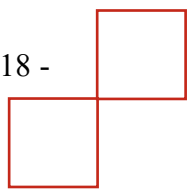
1.4.2 CAD-CAM

A scanner and software to analyze the data previously scanned, a fabrication system side in a laboratory, or at a centralized production center with the purpose of utilizing those data to manufacture the real repair are all part of a computer-aided design/computer-aided manufacturing (CAD/CAM) system (35). Their usage in esthetic dentistry is rising dramatically in recent years, from impressions, castings, and Provisionals through the final restoration (29)(35). The incorporation of the facial characteristics into digital diagnostic waxing operations is claimed to be made easier by 2D and 3D CAD software packages, nevertheless, the esthetic perception of the patient's virtual depiction may change depending on the system (28). The two major processes for creating a patient's virtual representation are facial and intraoral scanning operations, as well as superimposition procedures of the patient's digital information using the CAD/CAM system (36). A diagnostic wax-up can be elaborated using a variety of 2D, 3D and CAD software applications and superimposition procedures, which may overwhelm dental practitioners. There appears to be no limit nowadays, owing to CAD/CAM, with a wide range of treatments accessible, ranging from

simple indirect restorations to fully digitally designed and manufactured complete dentures (29).

1.4.3 Intraoral Scanners

Intraoral Scanner (IS) offer the opportunity to capture digital images of the mouth in real time, including single or multiple teeth, whole arches, opposing arches, and soft tissue (30)(37). As other 3D scanners, they work by projecting a light source, like laser or structured light onto the object of interest. Special sensors capture images of all intraoral features, which are subsequently processed by a scanning software, that generates point clouds out of the scanned dataset. The point clouds are subsequently processed by the same software, which creates a 3D surface model or mesh (37). Their efficacy is measured in trueness and precision: Trueness refers to how much an object or data set deviates from a reference object or point, whereas precision refers to measurement repeatability (37)(38). In terms of trueness, precision, and prosthetic quality, digital scans are on equivalent with, if not better than, traditional impression procedures. As new scanners and software upgrades are published daily, an assessment of their correctness is required to ensure that the process can persist (30)(37). It's unknown if the scan pattern approach influences the accuracy and precision of complete-arch scans, or whether there are changes in accuracy between scanners (29)(37). The scan pattern can have a significant impact on the outcome of the digital intraoral image (33)(38).



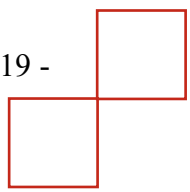
2. Justification, Hypothesis and Objectives

2.1. Justification

Every day, more patients are demanding extremely attractive clinical outcomes in contemporary dentistry. Dentists must conduct a full facial and dental analysis to enhance smile attractiveness, which will study their smile in an objective and standardized manner and resolve the patient's complaint. Facial, dentogingival, and dental esthetics must all be considered while performing an aesthetic assessment. Through innovative treatment methods, continually refining cosmetic dental materials and unique techniques and technologies, the possibility of achieving this goal has substantially improved over the last decade. The digital revolution is fundamentally transforming the world of dentistry by improving proficiency due to the development of a wide range of gadgets, tools, and software. With the use of technologies like Digital Smile Design, clinicians can plan each individual step for a successful dental aesthetic treatment. Traditional methods of dental restoration and treatment planning are rapidly being supplanted by digital processes. Digital imaging and design allow patients to see the anticipated outcome before the treatment is initiated, increasing the treatment's predictability. Dentistry is evolving and will continue to evolve, bringing innovations never imagined before. Unfortunately, dental professionals do not always embrace new innovations because they lack interest in testing new concepts, believing there is no need to change what has been researched previously, or just do not trust the advancements. It is the aim of this systematic review to give an overview about currently present DSD approaches in modern dentistry and highlight their advantages, advances, and satisfaction of the patients with their treatment outcome.

2.2. Hypothesis

The null hypothesis of this systematic review is that integrating Digital Smile Design improves the communication between the dentist, the



laboratory and the patient, and results in a more aesthetic and effective outcome and improves the patient's satisfaction with the treatment.

2.3. General Objective

The primary objective of this systematic review is to provide an overview of how present digital smile design methods are used in contemporary dentistry.

2.4. Specific Objectives

I. Analyze present digital smile design methods, dental treatment planning software and digital dental photography
II. Show benefits and advances of using digital smile design methods
III. Assess the degree of patient satisfaction with digital smile design approaches

3. Material and Methods

This systematic review was conducted according to the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (39). The latest publications were investigated to provide an overview of the current use of digital smile analysis in aesthetic dentistry.

3.1 Eligibility Criteria

The PICO question was used for the identification and structuring of the fundamental components of the systematic review, for which the following structured question was elaborated.

3.1.2 Identification of the PICO research question

A comprehensive literature search was held, which was conducted in the Online data bases PubMed, Medline, Cochrane, and Scopus to search for articles with scientific relevance indexed about the applications of digital smile design in dentistry published to answer the objectives and the following question: Is Digital Smile Design improving patient satisfaction and treatment outcomes, and is it efficient to employ DSD? The research question was implemented into this systematic review by applying the PICO research model (Population, Intervention, Comparison, Outcome*)* with the following terms:

P (Population): Patients who seek aesthetic dental treatment to improve their satisfaction with their smile
I (Intervention): Intervention of guided digital smile design (DSD) approaches
C (Comparison): No comparison parameter was defined for this systematic review
O (Outcome): Patients satisfaction is higher and treatment outcome is effective when employing DSD

3.2 Information resources and data research

All selected articles have been published in the English, Spanish or German language within the last 10 years, and the last search was performed on April 24, 2022. An automated search was carried out in the four databases mentioned above (PubMed, Medline Complete, Cochrane and Scopus) with the following keywords: ´aesthetic dentistry´, ´smile aesthetics´, ´digital smile analysis´, ´digital dentistry´, ´smile`, ´digital smile design`, `DSD´ and ´dental photography´. The research was divided according to the secondary objectives and keywords various combinations using the Boolean operator 'AND' and 'OR', as well as with the controlled term ("MeSH" for PubMed) to obtain the most accurate search results.

Table 1 Databases used for the research

Database	Search	Filters	Date
PubMed	The PubMed search was held by the following approach: ((aesthetic dentistry) [All Fields] AND (((digital dentistry) [MeSH Terms] OR digital smile design OR DSD) [All Fields] OR dental photography)) [MeSH Terms] AND ((((smile aesthetics) [MeSH Terms] OR ´smile`AND digital dentistry) [All Fields] OR digital smile analysis) "[MeSH Terms]	Date: January 2012 – April 2022 Languages: English OR Spanish OR German	24.04.2022
Medline Complete	ALL ((`digital smile design` OR `DSD`OR `digital dentistry` OR `digital smile analysis` OR `smile aesthetics` OR `smile` OR `aesthetic dentistry` AND `dental photography`))	Date: January 2012 – April 2022 Languages: English OR Spanish OR German	24.04.2022
Cochrane	ALL ((`digital smile design` OR `DSD`OR `digital dentistry` OR `digital smile analysis` OR `smile aesthetics` OR `smile` OR `aesthetic dentistry` AND `dental photography`))	Date: January 2012 – April 2022 Languages: English OR Spanish OR German	24.04.2022
Scopus	ALL ((`digital smile design` OR `DSD`OR `digital dentistry` OR `digital smile analysis` OR `smile aesthetics` OR `smile` OR `aesthetic dentistry` AND `dental photography`))	Date: January 2012 – April 2022 Languages: English OR Spanish OR German	24.04.2022

The titles of the articles resulting from the electronic search were screened for relevance and subsequently the articles complying with the topic of the literature review were selected. Further, the abstracts of the selected articles were screened for relevance. All articles not meeting the stated inclusion criteria or not containing relevant information were excluded in the full text review. Duplicates were removed. In addition to that, a hand search of the reference lists in the articles retrieved was carried out with the aim to find additional relevant publications and to improve the accuracy of this search. A manual hand search was held in the library *José Planas* of the European University of Valencia (UEV).

3.3 Inclusion Criteria

Inclusion criteria used for this systematic review are the following:

I. Articles published from 2012 and 2022
II. Patients who underwent smile design with any type of DSD software
III. Randomized and non-randomized clinical trials and Observational studies studying the effect of DSD
IV. Articles in English, Spanish, and German language

3.4 Exclusion Criteria

Exclusion criteria used for this systematic review are the following:

I. Articles involving patients with specific diseases, immunologic disorders or other oral risk-related systemic conditions or craniofacial discrepancies

II. Articles with a conflict of interest

III. Articles focusing on other technologies not related to digital dentistry or do not provide enough information regarding the selected topic

3.5 Systematic Search Strategy

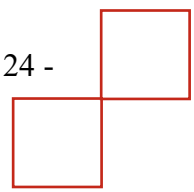
A three-stage selection process was carried out by two reviewers (VB and EG). The selection of studies was carried out by two reviewers. The first stage reviewed the titles to eliminate irrelevant studies. In the second stage, the summaries were reviewed and filtered according to type of study, type of digital intervention, number of patients, and outcome variables. The third stage consisted of a complete reading of each text and the data were extracted according to a predetermined data extraction form to confirm the eligibility of the studies.

3.6 Data Extraction

The data collected from the different articles is detailed by the name of the authors, year of publication, study design, number of included patients, patient satisfaction, Digital Smile Design tool, further digital dental approaches like the use of intraoral scanners and CAD/CAM, follow up period and overall risk of bias. The information of the sample includes sample size, male/female ratio and mean age in years.

3.7 Study Risk of Bias and Quality Assessment

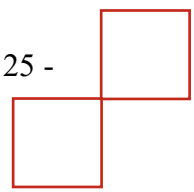
The quality of the included studies was assessed independently by two reviewers (VB and EG) to evaluate the methodological quality and risk of bias of all included articles. After removing duplicate sources, study titles and abstracts were reviewed to ensure they are relevant. Following that, studies that fulfilled the inclusion criteria were included after a full-text review.



4. Results

4.1 Results of Literature searches/ Study Selection

The article review and data extraction were performed according to the Preferred Reporting Items for Systemic Reviews and Metanalyses PRISMA flow diagram (Figure 1). The Literature research in the four online databases mentioned above (PubMed, Medline, Cochrane, and Scopus) identified a total of 237 potentially relevant articles. Out of the total number of 237 papers based on their title and abstract were selected, 62 were selected from PubMed, 79 from Medline, 12 from Cochrane and finally 84 from Scopus, being the first step of the research strategy. After 15 duplicates were removed, 222 articles were considered for title, abstract and summary evaluation and filtered according to intervention and outcome, the second step of the systematic research strategy. At the end of this evaluation, 72 relevant articles were identified for the third step of the research strategy, being the full text review. The full-text articles were subsequently obtained and thoroughly evaluated. For fulfilling the exclusion criteria 32 studies were excluded. For not meeting the inclusion criteria, 27 articles were excluded. A total of 13 relevant articles that fulfilled the inclusion criteria were selected for this systematic review (fig.1) after agreement by the two reviewers (VB, EG).



4.2 Flow-Chart

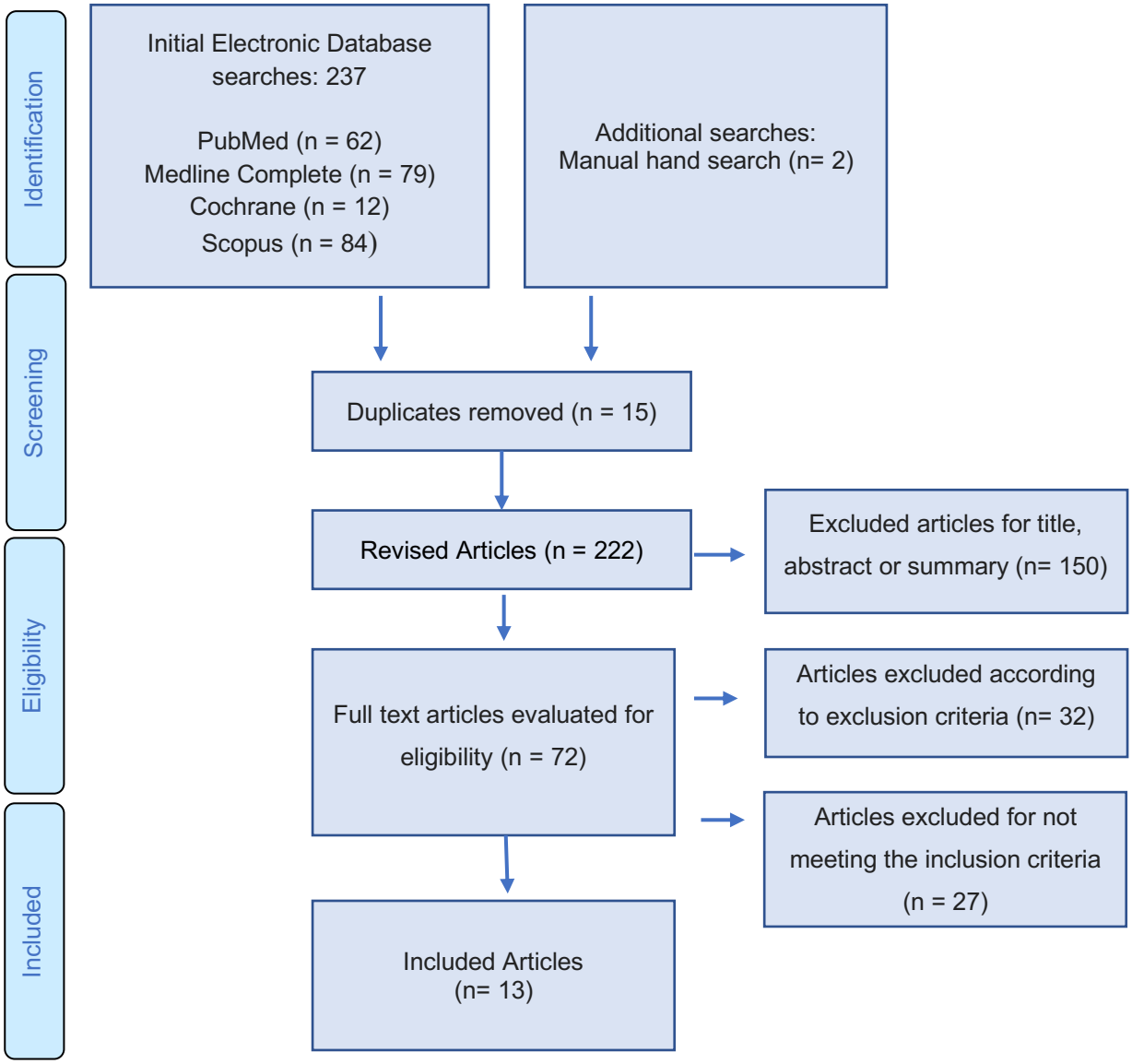


Fig. 1 Flow-Chart and study selection process for the systematic review

4.3 Selected studies according to the inclusion criteria

The study selection process is summarized in figure 1. The research's remaining 13 papers are constituted of 11 Observational studies (5,10,40,42-49) and two RCTs (41,50) and were confined to specific purposes based on the secondary objectives. Some investigations were beneficial for multiple

developments. Two authors (VB, EG) assessed the risk of bias during the data extraction process. A total of 689 subjects were analyzed in the included studies. The age of the participants was between 18 to 85 years of age and there were slightly more females than males included. It can be highlighted that mostly young adult patients were included. 12 different DSD software were evaluated and accessed. Each study assessed different parameters and covered a total of 5 different dentistry fields (Restorative and Esthetic Dentistry, Prosthodontics, Orthodontics, Implantology and Oral surgery). Four of the included studies were interdisciplinary regarding their field of dentistry. In addition, three of the studies had a follow-up period between 2 and 4 years. Seven of the included studies had their focus on 2D and 3D DSD methods and accessed their main characteristics, like parameters such as patients' satisfaction, efficiency, intuitiveness, understanding, reliability and measurement efficiency and stimulation degree (40-46, 50). Five of the included studies on the other hand explained use and highlighted effectiveness of Digital Photography (DP) in Dentistry (5,10,17,45,47-48) which is the basic requirement to develop DSD.

4.4 Bias Assessment

The included randomized controlled trials (RCTs) were considered "low risk of bias" when they met all the criteria, "high risk of bias" when one or more criteria were not met and therefore the study is considered to have a possible bias that weakens the reliability of the results and "uncertain bias" according to Cochrane Collaboration tool (either due to lack of information or uncertainty about the potential for bias). For each aspect of the quality assessment of the RCTS, the risk of bias was scored following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (http://handbook.cochrane.org). Each study featured varying degrees of heterogeneity in terms of design, case selection, and treatment applied. Risk of bias in the RCTs was categorized in accordance with the following criteria: low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met; unclear risk of bias (plausible bias that raises some doubt about the results) if one or more criteria were partially met; and high risk of bias (plausible

bias that seriously weakens confidence in the results) if one or more of the criteria were not met. The included RCTS were considered a unclear risk of bias. For non-randomized observational studies, the risk of bias was considered low in 8 studies and medium in 1 study. The Newcastle–Ottawa Scale (NOS) (fig.3) was used to assess the risk of bias in the included observational studies. One study scored a very low risk of bias with 9 out of 9 sections, while 6 studies had a low risk of bias with 8 out of 9 and only three studies scored 7 out of the 9 having a medium risk of bias. There were various degrees of heterogeneity in each study design, case selection, and DSD approach among the studies.

	Sequence Generation	Allocation concealment	Binding of participants and personal	Blinding outcome assessment	Incomplete outcome date	Selective Reporting	Other Bias
Cattoni et al. (2021)	+	+	+	?	+	+	−
Ye et al. (2020)	+	+	?	−	+	?	−

Fig. 2 Randomized studies risk of bias following Cochrane´s guidelines

	Case Definition	Representativeness	Selection of controls	Definition of controls	Comparability of main outcome	Comparability for additional factors	Ascertainment of exposure	Same method for ascertainment for case and controls	Drop-out rate	Total
Cattoni et al. (2016)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Lavorgna et al. (2019)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Lv et al. (2022)	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Pires et al. (2022)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Lo Giudice et al. (2020)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Ortensi et al. (2021)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Ramaswamy et al. (2021)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Varghese et al. (2021)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Iliev et al. (2020)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Husain et al. (2017)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Signori et al. (2018)	☆	☆	☆	☆	☆	-	☆	☆	☆	8

Fig. 3 Observational non-randomized studies according to Newcastle-Ottawa scale

4.5 Results of Individual Studies

The research of Cattoni et al. focuses on using digital photos from the 2D DSS software and matching a scanned file into the 3D DSS to generate a previsualization of teeth and a smile design. However, the current study has limitations, such as the small number of patients enrolled, demanding additional research with a wider sample of subjects to corroborate the findings. The new techniques shorten the time required to match data in order to create digital CAD/CAM-milling mockups and enhances the precision and reproducibility of the final mockup, and minimizes the trauma caused by handling hard dental tissues (40). In a subsequent study published in 2021, Cattoni et al. used a digital protocol that allows for a completely virtual planning of the exact position of the fixtures, allowing for high-precision surgical procedures and the use of virtually designed dental prostheses created with CAD/CAM methodologies for immediate implant loading (41).

Lavorgna et al. evaluates the accuracy of digital planning in dentistry by relating it to classic imaging 2D recording methods and examining the properties of four intraoral 3D scanners. Because there were no considerable disparities in measures, they concluded that 2D measures are faster and easier to use than all 3D approaches. Therefore, this research can assist to better define the field of application and the limitations of 2D approaches. The findings further suggested that In terms of the 2D/3D comparison, it's worth noting that 2D and 3D measurements can only be identical if 2D images are taken with the plane of the camera sensor absolutely perpendicular to the observed item and the surface of the observed subject is perfectly flat (42). Lv et al. findings where according to the patients' ratings, that the 3D digital simulated treatment plan showed obvious advantages in terms of intuitiveness and understanding of the treatment plan, as well as greater satisfaction rates than DSD with conventional wax-up. The authors state that the 3D digital simulated treatment plan was also superior in terms of intuitiveness and treatment plan knowledge (43). According to Pires et al., the mock-up presented in the study effectively transferred the intended dental crown lengthening with DSD to the surgical procedure. The authors confirm that esthetic crown lengthening and restorative protocol proposed, based on

the DSD concept and mock-up technique, is a predictable treatment to correct smile disharmony in all participating patients (44) (Table 2a).

According to Lo Giudice et al. with ANOVA analysis, important differences were detected across the 3D project and the prototyped-scanned anterior mock-ups (p 0.001), as well as between 3D project milled and milled-scanned anterior mock-ups (p 0.001). In comparison to milled mock-ups, prototyped mock-ups demonstrated smaller dimensional alterations from the original 3D idea, as well as greater clinical adaptability (45). Except for the mesial–distal widths of the lateral incisors and canine, which showed a substantial increase in digital scans, Ortensi et al. discovered no significant changes between the heights determined from the photos and those assessed from the digital scans. It's possible that the primary inclination of the dental parts involved is to blame for the disparity. The result reveals that the disparities in mesiodistal widths reported in photographs and digital scans were related to the transition from a 2D to a 3D environment (46). The findings of Ramaswamy et al. revealed that several smiling parameters measured can be used to rehabilitate the smile of dentate, partially dentate, and edentulous patients. The purpose of this study was to use pictures to examine various characteristics of the dento-labial-gingival complex. Dentists may diagnose, develop, create, and deliver esthetically pleasing new smiles using their knowledge of smile design combined with new and revolutionary dental technologies (5). Varghese et al. adopts a digital photographic design to accomplish a study on proportions on maxillary anterior teeth for esthetic smile. The golden percentage theory appears to be relevant to link the consecutive widths of the maxillary anterior teeth. The golden rectangle concept is useful for selecting aesthetically attractive proportions for maxillary central incisors (10) (Table 2b).

Iliev et al. uses Rebel Simplicity technologies to analyze 91 full-face smile images using dental Anatomical Combinations and computer analysis. The finding is that the technique resulted positive to ensure that the teeth and the facial type are in harmony. While smiling, digital facial maps allow an accurate and quick detection of the facial type. This examination allows to produce a digital design for an accurate and beautiful anterior tooth prosthetic

replacement (47). Husain et al. establishes a two-dimensional dynamic video technology that records the smile employing multidirectional, remote-controlled, synchronously moving camera holding arms that hold digital single lens reflex cameras with high-definition video capture for use in everyday practice. The cameras in this setup can be used for both static and dynamic records in a consistent manner in terms of magnification and head position orientation. This is both efficient and economical (48). The outcomes of this study by Signori et al. revealed that the intraoral photography approach in the identification of restoration failures have good accuracy and reasonable agreement. Considering these findings, as well as the sensitivity, specificity, predictive values, and positive and negative probability ratios, we may infer that digital intraoral imaging can be used to assess the quality of restorations, particularly in the posterior teeth (49). Three-dimensional digital simulated design and implementation technique, according to Ye et al., can aid in achieving 3D digital simulated design before treatment and duplication to final restorations, as well as improve patient satisfaction in esthetic rehabilitation (50) (Table 2c).

4.6 Tables

The following tables include the conclusion and other relevant data of the selected studies based on the specific objectives of this systematic review. The DSD system employed, and the main outcome of the included studies is summarized in Tables 2a-2c. Table 3 focusses on the benefits and advances of using digital smile design methods, whereas Table 4 does a further assessment of the effectiveness and the degree of patient satisfaction.

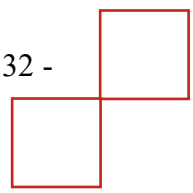


Table 2a – Summary of present digital smile design methods and dental treatment planning software

Authors & Year of Publication	Study Design	Field of Dentistry	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Cattoni et al. (2016) (40)	Observational Study 2- Years Follow-Up	Restorative Dentistry	2D-Digital Smile System (Digital Smile System Srl, Italy) 3D-Digital Smile System (EGS Srl, Italy)	28 patients (9 males, 19 females)	19-53 years of age	Patient satisfaction with DSD previsualization and the milling mock-up test	Visual analogical scale (VAS scale) to determine satisfaction with the digital smile design planning and the test in the form of the mockup	The patients considered DSD previsualization and the milling mockup test as very effective
Cattoni et al. (2021) (41)	RCT 4-Years Follow-Up	Implantology	Smile Lynx software (8853 S.P.A., Milan, Italy) CAD software (CAD Lynx 8853 S.P.A., Milan, Italy)	50 patients randomly recruited and divided in 2 groups of 25	46 -85 years of age	Satisfaction with Digital smile previsualization, Mock-up test, Guided surgery, Immediate loading	Verbal Rating Scale (VRS)	All patients treated with a digital method reported lower values of during-surgery and post-surgery pain compared to patients rehabilitated using traditional treatment. Patients belonging to the digital group found digital smile preview and the mock-up test as very effective
Lavorgna et al. (2019) (42)	Observational study	Dental Prosthodontics	Emerald, TRIOS, Photogrammetry and DSS	12 patients (6 female, 6 male)	25 to 35 years of age	Differences in measurements of the different tool data (Emerald, TRIOS, Photogrammetry and DSS) in terms of reliability and accuracy	Statistical analysis was performed using statistical software (Prism 8.0; GraphPad Software, Inc., La Jolla, CA, USA)	No significant differences emerged in the measurements made with the different scanners. The difficulty on comparing 2D with 3D investigations was highlighted
Lv et al. (2022) (43)	Observational study	Restorative Dentistry, Orthodontics and Prosthodontics	2D DSD Software not further specified, intervention according to the established protocol of DSD3D Workflow by 3D-SHAPE, (Denmark)	11 patients (2 males and 9 females)	19 to 36 years of age	Difference between Intuitiveness, understanding, and satisfaction or help (dentists) in 3D treatment stimulation or 2D DSD plus wax-up technique	Visual analogue scales & Statistical analysis. Paired t-test was performed, and the level of significance was set at $P < 0.05$	3D digital plans are more intuitive (8 .9 ± 0.8 vs 5.9 ± 1.0) to understand the plans from the other specialists (8.9 ± 0.7 vs 6.1 ± 1.0) and helpful to their treatment plans (8.7 ± 0.9 vs 5.9 ± 1.4)
Pires et al. (2022) (44)	Observational Study 2-year follow-up	Oral Surgery, Restorative Dentistry	PowerPoint (Microsoft) for DSD planning of all cases	6 patients (5 females, 1 male)	22 to 35 years of age	Mean and standard deviation of the dental crown length in the anterior teeth at baseline, immediately postoperatively at the 2-year follow-up, and the years of age crown length planned by the DSD	Statistical Analysis: The measurements were repeated twice with an interval of 1 week, and the Pearson's correlation coefficient was used to assess the calibration of the evaluator concerning the analyzes performed.	Esthetic crown lengthening procedure based on the DSD concept and mock-up technique proposed in this study was a predictable protocol for smile disharmony treatment in all the patients

Table 2b – Summary of present digital smile design methods and dental treatment planning software

Authors & Year of Publication	Study Design	Field of Dentistry	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Lo Giudice et al. (2020) (45)	Observational Study	Restorative Dentistry	2D DSS system (version 1.11.1-alpha.1, Digital Smile System Srl, Italy); DSS CAD software (DSS3D. Beta.12977, EGS Srl, Italy)	10 patients (8 females and 2 males, mean age)	N/A	Matching percentage of prototyped and milled mock-ups with 3D project Comparison of linear measurements (mm3) performed on 3D project, prototyped, and prototyped-scanned anterior mock-ups	Statistical analysis: The trueness of both prototyped and milled mock-ups was assessed by using the Paired Student's t test. The two-way analysis of variance (ANOVA) was used to assess if there were statistical differences among the linear measurements obtained at each stage of the entire CADCAM workflow	Both prototype and milled mock-ups showed a slight dimensional increment in comparison with the original 3D project. Prototyped mock-ups demonstrated few dimensional changes from the original 3D project compared to the milled mock-ups as well as a greater clinical adaptation
Ortensi et al. (2021) (46)	Observational study	Restorative Dentistry	2D DSS (Digital Smile System Srl); 3D Exocad® DentalCAD 2.2 Valletta software (Exocad GmbH) Shape 3D Viewer software (3Shape A/S)	30 patients (18 women and 12 men)	20 - 50 years of age	Linear measurements of the maxillary right central and lateral incisors and canine; mesial–distal widths of the restorations Consistency between the 2D virtual preview of the treatment and the restorations	The Friedman test, Bonferroni, and Dunn post hoc tests were used, comparing the linear measurements of the 2D and 3D plans and the final veneers (α =.05). Measurement data were statistically analyzed using a software program (Prism 8.0; GraphPad Software, San Diego, CA, USA)	The customized are clinically adequate, like the 2D and 3D plans previsualization. There are significant differences between the picture and digital scans as well as between the 2D and 3D plans.
Ramaswamy et al. (2021) (5)	Observational Study	Restorative Dentistry and Prosthodontics	DP DSLR [Single-lens reflex digital camera (NIKON)	120 patients (60 males and 60 females)	male mean age: 21.97 female mean age: 22.20.	240 photographs, 2 of each patient being a close-up (natural and forced smiles) and facial photographs Parameters assessed were Smile Arc; Gingival Visibility; Facial and dental midline; Gingival zenith pattern and relationship between the smile arc and lower lip	Statistical analysis Chi-square test and Fisher's exact test were used to compare the link between gender and various parameters. Comparison between two groups or various parameters was done by non-parametric Mann–Whitney "U" test. The p value of 0.05 was statistically significant.	With DP as an aid, the dentists can design and correct the smile for the utmost satisfaction of the patients.
Varghese et al. (2021) (10)	Observational Study	Esthetic Dentistry and Prosthodontics	Adobe Photoshop CS5; (Adobe Systems, Inc, San Jose, Calif.)	150 subjects (male/female ratio N/A)	18 – 25 years of age	Full-face digital images of subjects in smile will be made, with the subject in a seated position. Golden ratio, Golden rectangle & RED (Recurring esthetic dental) proportion were assessed	The data were statistically analyzed using paired Student's t-test (level of significance P ≤ 0.05)	The golden ratio appears to be relevant to link the consecutive widths of the maxillary anterior teeth. The golden rectangle concept is useful for selecting aesthetically attractive dimensions for maxillary central incisors. The RED proportion is an inadequate approach for relating the sequential widths of the maxillary anterior teeth, according to DP and analyses.

Table 2c – Summary of present digital smile design methods and dental treatment planning software

Authors & Year of Publication	Study Design	Field of Dentistry	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Iliev et al. (2020) (47)	Observational Study	Restorative Dentistry and Prosthodontics	Digital Facial Maps with Rebel Simplicity systems	42 male and 49 female subjects	N/A	Subjects were categorized into four main types: Strong, dynamic, delicate, and calm by 27 landmark points and 12 basic lines	IBM SPSS Modeler software	Dental Anatomical Combinations in combination with Rebel Simplicity systems is a constructive way to ensure harmonious unity between the teeth and the facial type.
Husain et al. (2017) (48)	Observational Study	Orthodontics	The captured video frames were saved as pictures using screen-shot software and analyzed using custom software called “smile mesh.”	96 subjects (48 female and 48 male)	18 -28 years of age	Reliability and measurement errors for images made on the same day (3 images) and on 3 different days	Reliability expressed by Pearson correlation coefficient. Results of the paired t test for the mean difference (P values).	Capturing standardized high-definition video and still images simultaneously from 3 positions is described. It resulted practical, effective, and easy to learn and implement in the orthodontic practice
Signori et al. (2018) (49)	Observational Study	Restorative Dentistry	The digital intraoral camera CS 1200 (Carestream Health Inc, Rochester, New York, USA	55 patients with 198 restorations, aged between (128 posterior and 70 anterior restorations)	18 - 57 years of age	Intraoral photographs of anterior and posterior restorations were classified based on FDI criteria according to the need for intervention: no intervention, repair, and replacement. The prevalence of failures was explored.	Evaluations were performed by an expert in restorative dentistry (gold standard evaluator) and 3 trained dentists (consensus) Validity was accessed by sensitivity, specificity, likelihood ratio and predictive values.	The assessment of DP performed by intraoral camera is an indirect diagnostic method valid for the evaluation of dental restorations, mainly in posterior teeth. This method is effective due the higher detection of defects provided by the images, which are not always clinically relevant.
Ye et al. (2020) (50)	RCT	Restorative and Esthetic Dentistry	3D digital simulated design was used to predict the post-treatment effect in the experimental group and 2D digital smile design in the control group	30 patients were recruited and randomly assigned into 2 groups (10 males, 20 females)	Experimental group mean age: 36.0±10.5 Control group mean age: 32.0±6.7	The simulation degree of DSD and the similarity between preoperative design and postoperative rehabilitation were assessed	Visual analogue scales (VAS) and satisfaction rate	Three-dimensional digital simulated design and implementation technique aid in achieving 3D digital simulated design before treatment and duplication of the final restorations and can enhance the patients’ satisfaction with the treatment outcome than in the control group (P<0.05).

Table 3 – Benefits and advances of using digital smile design methods

Study	Sample	Benefits	Advances	Conclusion
Cattoni et al. (2016) (40)	28 patients	DSD reduces time spent in the clinic and laboratory, increases the predictability of data matching to build CAD/CAM milling mockups and minimizes trauma caused by handling hard dental tissues, and improves accuracy and reproducibility of the final mockup	DSD planning technique is minimally invasive and facilitates diagnosis, improves communication with the patient, reduces processing times, and increases predictability of the results with very little discomfort and very high esthetic results	DSD is highly advanced and therefore beneficial in all prosthodontic aesthetic treatments: The accurate design planning and the basic communication phase with the patient has a vital meaning
Ramaswamy et al. (2021) (5)	120 patients	DP offers the dental professional the possibility of visual reconstruction during treatment. With DP as an aid, the dentists can design and correct the smile for satisfaction of the patients	Clinical photography has become an important part of standard dental practice	Knowledge of smile design and new and innovative dental technologies makes it possible to diagnose, plan, create, and achieve beautiful new smiles
Ortensi et al. (2021) (46)	30 patients	Customized composite veneers can be achieved following either a 2D or a 3D clinical plan, which are comparable. New digital measurement system can achieve accurate results in treatment planning	Digital measurement system can achieve esthetic results in digital planning for customized composite veneers. measurements with DSS are clinically relevant because it represents the tool used by dentists in their routine	More studies with a larger sample, alternative materials and digital systems are necessary to further confirm these results
Lavorgna et al. (2019) (42)	12 patients	The DSS photographic protocol requires less sophisticated equipment, is economically inexpensive and is normally presented in the common dental practices	2D measurements are fast and simple compared to all 3D techniques, so this work can help to better define the field of application and the limits connected to 2D techniques, giving a good window of the technique.	The limitations were the short number of the involved patients and mainly connected to the difficulty on comparing 2D with 3D investigations, this study could be considered a starting point to carry out another research
Iliev et al. (2020) (47)	91 patients	Rebel Simplicity systems are a good technique to ensure that the teeth and the facial type are in harmony.	The merging of 2D designs and 3D digital models allows for prosthetic constructions to be completed digitally, and scanned models can then be transferred to the final design of the restoration	Digital facial maps provide reliable and fast identification of the facial type while smiling. This analysis enables the creation of a digital design for the prosthetic restoration of the anterior teeth

Table 4 – Assessment of the degree of patient satisfaction

Study	Sample	Assessment scale	Classification	Patient-related outcome
Cattoni et al. (2016) (40)	28 patients	VAS	Appreciation of the previsualization classified in very effective, effective, and ineffective	For the digital smile design previsualization, with visual analogical scale (VAS scale), 18 (64%) of patients found it very effective and 10 (36%) effective; 24 (86%) found the milling mockup very effective and 4 (14%) effective
Cattoni et al. (2021) (41)	50 patients separated equally in 2 groups	VRS & VAS	1 = very effective 2 = effective 3 = ineffective	93% out of 25 patients found the Digital Smile previsualization very effective, the remaining 7% found it effective. In the Traditional group 45% of the 25 patients found the mock-up test very effective and 37 effective and 18 ineffective
Ye et al. (2020) (50)	30 patients separated equally in 2 groups	VAS	Very effective, effective, and ineffective	The VAS score on the simulation degree of digital design in the experimental group, 3D digital smile design (8.5+/-0.5) was higher than that in the control group (7.2+/-0.7) (P<0.01) being 2D digital smile design
Lv et al. (2022) (43)	11 patients	VAS	From 0 to 10, with 0 indicating “very poor” and 10 “very good”-	According to the patients, 3D treatment simulation showed obvious advantages in intuitiveness (9.7 ± 0.5 vs 6.4 ± 1.4) and treatment understanding (9.1 ± 0.8 vs 6.6 ± 1.5), and the satisfaction was also higher (9.0 ± 0.6 vs 7.1 ± 1.8)

5. Discussion

One of the most significant facial functions, the smile, is frequently used to assess success or failure in life, particularly from a patient's perspective. One´s smile is a sensible but also intimate facial feature and everything that comes with the expectations to modify it is a highly emotional concern for a patient, that the dentist needs to keep in mind while designing a new smile (34). Nowadays, digital technology is frequently employed for facial identification from images or videos by facial contour analysis (47). As part of the esthetic rehabilitation process, a full examination is required, which includes a face analysis, dental-facial analysis, and dental analysis. The importance of a good communication with the patient in all dental aesthetic treatments cannot be emphasized enough. Any effort should be made in modern dentistry to improve the communication of diagnosis and therapy with the patients and amongst dentists. In this regard, virtual planning combined with a mock-up-based approach improves the accuracy of aesthetic treatments by enhancing the knowledge of patients' demands and the information-sharing process between prosthodontists and lab technicians (45).

New computer programs and other software allow the dental professional to perform DSD and envision aesthetic results, while building a fundament for a multidisciplinary aesthetic treatment, with the assistance of static or photographic and dynamic videography recordings. Effective digital previsualization together with a mockup is the best way to communicate desired alterations in their smile to a patient and receive their consent (43). It should be guaranteed that therapeutic pre-visualization using is accurate, facilitating the design of restorations to be dimensionally proportional to the anatomy of the patient (42). Conventional "non-digital" procedures on the other hand rely on a planning process that involves radiological and clinical assessment, intra- and extraoral analysis, static and dynamic occlusal examination, and conventional impressions taking (40). The correct therapeutic planning, digital photographs connected with the production of a mockup is the basic requirement for DSD (43).

5.1 Introduction of DSD Methods, Dental Treatment Planning Software and Digital Dental Photography

5.1.1 Digital Smile Design and Dental Treatment Planning Software

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. Omar et al. conducted a literature review in which different software were evaluated (*Photoshop CS6, Keynote, Planmeca Romexis Smile Design, CEREC SW 4.2, Aesthetic Digital Smile Design, Smile Designer Pro, DSD App*, and *VisagiSMile*). The possibility of having functions concerning oral structures, such as teeth or gums, makes the work much quicker and more predictable in this study, different programs were evaluated. The authors also pointed out that photoshop and keynote were not specially created for DSD. In their study these two programs were able to especially define, measure and modify a high number of dentofacial aesthetic parameters which were taken into consideration for their study. The highest scores were observed in *Photoshop CS6* and *Keynote*; therefore, more comprehensive esthetic analysis can be achieved using these programs even though they are not specific for dental practice. Most programs specific for dental practice seem to overlook facial esthetic parameters and focus on dentogingival and dental esthetic parameters instead. The competency of *Keynote* in DSD has also been described in the literature. Like *Photoshop*, *Keynote* provides the ability to define reference lines and angles and obtain the needed measurements. The *DSD App* on the other hand is being developed by Christian Coachman who published studies on the use of Keynote for digital smile design and, therefore, shows similarities with the image editing software (34).

Classic aesthetic evaluation and treatment guidelines were based before on 2D measurements. More recent clinical studies evaluated 3D surface analysis of scanned teeth and faces and showed findings in contrast to traditional paradigms and classic studies on aesthetic parameters. Prosthetic treatment planning is accomplished by using a digital workflow in a study by Cattoni

et al. According to the authors, the limit of these technologies is a two-dimensional (2D) workflow. The approach used by the authors in this case gives a completely digital CAD/CAM procedure to reduce mistakes. The dental lab receives the three-dimensional (3D) planning and fabricates the prosthetic pieces. The combination of the DSD digital process with the stl-files from the digital optical impression enables for the laboratory production of these objects. The authors also add to their findings that Digital technology, such as a computer with one of the various DSD software programs, a digital camera, or even just a smartphone, is already widespread in today's dentistry clinics (40). As mentioned per Cervino et al., with software advances in the near future, it will be possible to design a patient's rehabilitation by integrating files from a CT scan or a Cone Beam, as well as the stl-files from an oral impression or a facial scan and a photo. All of this ensures that the patients receive the therapy they seek, as well as their personal satisfaction (2).

Ortensi et al. investigates to see if computerized planning for individualized composite veneers was accurate. They draw the conclusion that DSS assessments are clinically meaningful since DSS is a tool that dentists and lab technicians utilize on a daily basis. *Exocad* measurements, on the other hand, are less useful and instructive for operators due to the high cost and complexity of the 3D *Exocad* software, which limits their use in clinical practice. These findings demonstrated the clinical suitability of the personalized veneers, which were clinically examined and found to fit well. The authors also mentioned that the small sample size and the type of material and software examined could be limitations. To confirm, more research with a bigger sample of people, as well as different materials and digital systems, are required (46). Lo Giudice et al. on the other hand claimed that employing software that has both 2D and 3D capabilities, such as *Exocad*, will speed up the workflow and make the entire process more fluid and efficient (45).

According to Cattoni et al. DSD plays also in important role in modern Implantology. The therapeutic efficacy of rehabilitations based on the use of fewer implants, with a high aesthetic and functional output, is now generally accepted in Implantology. The current clinical trial has some shortcomings, the

most significant of which is the lack of follow-up. This type of research would necessitate a longer period of follow-up. More research with a greater number of patients is also required. The findings suggest that the current digital protocol for implant-supported rehabilitation of edentulous arches is a viable therapeutic alternative to the traditional "All on Four" technique. With the advancement of technology, it is envisaged that a digital workflow would become even more simple and accessible to any dental professional. (41). As in another systematic review mentioned by Cicciú et al. evaluation on how digital workflows provide accuracy and predictability was done. The authors ruled it a reliable alternative for full arch rehabilitations with a marginal fit precision and also underlined the trend how digital techniques will substitute the analogical ones more and more, improving the quality of oral rehabilitations, the clinical economics and also the perception by the patients (51). In another study by Cattoni et al. they highlighted patients' appreciation of digital aesthetic planning in 2016 by using a VAS-type scale to evaluate each patient's satisfaction with the final aesthetic result of the fitting of ceramic crowns and veneers in the anterior regions (40). On another interesting note, Cattoni et al. in 2020 found that there is a possible neurocognitive measurement of how one's opinion of themselves changes as a substantial result of aesthetic prosthetic rehabilitation reduced for all other situations, including self-portraying photographs before the intervention and pictures of others (41).

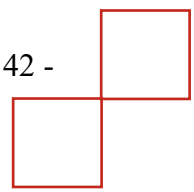
Face and smile are not perfectly symmetrical, rather, they are dynamic. According to Garcia et al., the employment of current digital technologies in the dental clinic provides new potential. The authors looked at a front maxillary prosthesis rehabilitation that was created using Digital Smile Design. They find that it is effective for diagnosing and also serves as a useful tool for recommending treatment regimens to patients (52). The DSD approach allows for esthetic planning by establishing reference lines and employing extra- and intraoral digital photographs to achieve the final dental design. This method expands the diagnostic range and aids dentists and technicians in recognizing treatment boundaries and difficulties including tooth asymmetries, disharmonies, and esthetic violations. DSD is a new instrument around

cosmetic and restorative dentistry that has only lately been introduced. For objective esthetic evaluations and virtual therapeutic planning, DSD apps are used to alter photos and/or scanned models of patients. However, a range of 2D and 3D dental and non-dental CAD software tools and superimposition methods can be used to create a facially oriented diagnostic wax-up, which might be overwhelming for dental practitioners (28).

5.1.2 Digital Photography in Dentistry

Dental photography provides the dentist with a variety of options for visual reconstruction of various phases of therapy. Clinicians can develop and fix smiles for patients' ultimate satisfaction using DP as a tool. Clinical diagnosis is a subjective procedure that can lead to a variety of interpretations, even among experienced physicians, depending on how cautious they are. Taking these findings into account, as well as sensitivity, specificity, predictive values, and positive and negative likelihood ratios, the authors conclude that intraoral DP can be used to examine the quality of restorations, particularly in the posterior teeth. The study by Signori et al. manifests that the use of intraoral digital imaging to evaluate dental restorations is a reliable procedure (49).

Ramaswamy et al. concluded that DP provides the dentist with a wide range of visual reconstruction options at different phases of therapy of the dental treatment. Clinicians can use DP to develop and restore smiles for the highest level of patient satisfaction. Clinical photography has become an important aspect of routine dentistry practice, according to the authors (5). Husain et al. introduced a new approach to capture standardized high-definition video and still images simultaneously from 3 positions. He describes the technique as efficient and simple. The authors express the great interest in 3D capturing of the human face. However, standardized dynamic 3D video capture and a measuring system are still in the experimental phases and also that the huge amount of data produced by 3D video imaging needs high-end computer equipment for processing (48).



Another study by Varghese et al. used pictures to assess various elements of the dento-labial-gingival complex. Dentists may diagnose, develop, create, and deliver esthetically pleasing new smiles using their knowledge of smile design combined with new and revolutionary dental technologies. The research was done on smiles that were captured by clinical photography and were a static record. Although also *Adobe Photoshop* was employed in this study, advanced software is available that could be used in future research (10).

5.2 Benefits and Advances by using DSD

As mentioned by Cicciú et al. the introduction of new technology in the fields of medicine and dentistry is resulting in advancements that enable dentists to develop techniques and treatments that can enhance the quality of life of their patients (51). Pires concluded that from a communicative point of view virtual planning combined with a mock-up-based approach improves the predictability of aesthetic restorations by enhancing the comprehension of patients' expectations and the information-sharing process between prosthodontists and the dental lab workers (44). However, as Lv et al. mentions the main disadvantage is that the dentist must have a moderate to advanced level of training to use the software functionalities in the smile design process. Currently, the trend is observed that the awareness and aesthetic expectations on dental treatments are increasing. The authors further mention that the DSS photographic procedure involves less complicated equipment, is more cost effective, and is commonly used in dental offices. They emphasized that the speed and simplicity of 2D studies are superior to all 3D processes. Within the limitations of the high differences between 2D and 3D approaches, these findings can define the field of application and limitations of 2D techniques, indicating a place for the technology in dentistry (43). When used in conjunction with standard treatment planning methods, Iliev et al. observed that computerized technologies can provide a more cautious approach and a more predictable outcome. Prosthetic restorations can now be finished digitally thanks to the combination of 2D designs and 3D digital models, and scanned models can then be

translated to the restoration's final design. They further highlighted the possibility that the new 3D smile design is delivered back to the clinician/technician in the form of an stl-file in minutes, making it quick and economical. The clinician/technician can print the data in 3D after obtaining the file and have a true 3D design of the new smile right away (47). Cervino et al. further point out the advantage that patients can visualize their future rehabilitations before the treatment starts, which can serve an essential medico-legal purpose (2).

According to Lavorgna et al, it is important to guarantee that pre-visualization of treatment using a virtual patient is accurate and that it enables for the design of restorations that are dimensionally relevant to the anatomy of the real patient. Even though the statistical analysis did not exhibit significant differences, the study demonstrated that 3D approaches for recognizing the patient's dental and facial features, particularly the digital photography of the DSS protocol, are reliable (42). As Omar et al. have also remarked, not all DSD applications on the market today have the same level of skill when it comes to full analysis of dentofacial aesthetic characteristics. Although simplicity of use is one of the most important factors to consider when selecting a DSD program, other factors such as cost, time efficiency, systematic digital workflow and organization, and compatibility of the program with CAD/CAM or other digital systems may also impact the clinician's decision (34). In another systematic review, Joda et al described the whole computerized approach as the potential to be a game changer in fixed prosthodontics. In a modernized treatment concept, major benefits could include lower manufacturing costs, improved time efficiency, and patient satisfaction (53). By offering a speed of treatment planning and a reliability of results, Cervino et al. emphasize that advancement in the digital dentistry sector is constant and will be of increasing importance to dentistry (2).

5.3 Patient Satisfaction and Understanding regarding DSD Approaches

According to Lv et al. 3D digital treatment simulation helps both patients and dental specialists to improve treatment understanding and facilitates dental

specialists for decision-making before complex esthetic rehabilitation. Highlighting the ratings from the patients, the authors concluded that 3D digital simulated treatment plan showed obvious advantages in the aspects of intuitiveness and understanding of the treatment plan, and the satisfaction rates were also higher than DSD plus conventional wax-up (43). Also Cattoni et al. results show that majority of included patients decided that previsualization with DSD is very effective, where a smaller part ruled it effective and not a single patient found it ineffective (40). Another RCT by Cattoni et al. confirms this since the majority of the 50 patients treated with Implants considered the DSD previsualization as very effective (41). Ramaswamy highlights that dentists can use DP to develop and restore smiles for the highest level of patient satisfaction (5). As concluded by Joda et al. the appropriate indication is a prerequisite and the correct application is absolutely crucial for the success of the overall therapy, and finally, for a satisfied patient (53).

A systematic review conducted by Ye et al. assessed the degree of digital design simulation and the similarity between preoperative design and postoperative rehabilitation using a VAS scale in both groups, as well as the patient satisfaction rate with the treatment. The authors concluded that achieving a 3D digital simulated design before treatment and duplication to the final restorations can improve the patients' satisfaction in esthetic rehabilitation (50). Industrial advancement appears to be outpacing scientific evidence. This is a significant result, and one that will stimulate the attention of clinicians who must determine whether or not to engage with DSD and adopt comprehensive digital processes in their dental practices (53).

Overall, the scientific level of clinical evidence was lacking in the field of DSD and DSS. Only two RCTs could be included for this systematic review. The study designs and follow-up periods as well as the defined outcomes were heterogeneous. This also applied to the lower included evidence level being the observational studies which draws the conclusion that more qualitative research on DSD in the future is needed.

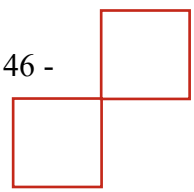
6. Conclusion

With the evidence of the included studies to provide an overview about how present digital smile design methods are used in contemporary dentistry, this systematic review concludes that:

1. The DSD methodology enables for aesthetic planning by using extra- and intraoral digital pictures to establish reference lines and the final dental design. This approach broadens the diagnostic spectrum and assists dental professionals in identifying treatment restrictions and risk factors such as asymmetries, disharmonies, and aesthetic violations. Since DSD is a relatively new digital innovation in dentistry further research is still lacking to investigate it to a deeper extent. However, there is already and increased usage trend of DSD approaches.

2. The DSD protocol improves treatment predictability and simplifies communication between dentists, patients, and dental technicians. DSD and Dental Photography are already of widespread and interdisciplinary use in contemporary dentistry. It is the creation of a strong communication protocol that allows for an efficient dental treatment, while also increasing its perceived value.

3. By integrating the patient into a founder of his own new smile, DSD not only improves treatment planning and the smile designing process, but also the patient's satisfaction with the treatment outcome. Results have demonstrated that the previsualization with DSD is considered as very effective by patients and dental professionals.



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8. Annex

8.1 Prisma 2020 Checklist

Table 5 - Prisma 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	cover page
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	5
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	19
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	20
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	23
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	22
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	22
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	24
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	24
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	-
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	-
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	27-29
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	-

Section and Topic	Item #	Checklist item	Location where item is reported
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	-
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	-
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	-
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	-
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	-
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	-
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	27
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	27
Study characteristics	17	Cite each included study and present its characteristics.	30-32
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	27-29
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	30-35
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	-
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	-

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	-
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	38-45
	23b	Discuss any limitations of the evidence included in the review.	45-46
	23c	Discuss any limitations of the review processes used.	45-46
	23d	Discuss implications of the results for practice, policy, and future research.	45-46
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	-
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	-
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	-
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	-
Competing interests	26	Declare any competing interests of review authors.	-
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	-

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

8.2 Article

The current use and effectiveness of Digital Smile Design in contemporary dentistry – A Systematic Review

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Background: Digital Smile Design is a new tool in esthetic dentistry with the purpose of facilitating previsualization of the treatment outcome and to improve communication between dentist, technician, and patient. To perform DSD knowledge of dental aesthetic guidelines is vital. **Objectives**: The aim of this systematic review is to analyze present DSD methods, dental treatment planning software and digital dental photography, to show their benefits and advances and to assess the degree of patient satisfaction in treatment planning with DSD. **Materials and Method**s: A comprehensive literature search was conducted in the online data bases PubMed, Medline, Cochrane, and Scopus to search for articles with scientific relevance indexed about the applications of digital smile analysis in dentistry. Inclusion criteria where publication within 2012 and 2022, DSD with any type of software, RCTs and non-randomized clinical trials, Observational studies and Case Series studying the effect of DSD and English, Spanish, or German language. Exclusion criteria patients with specific diseases, immunologic disorders or other oral risk-related systemic conditions or craniofacial discrepancies, studies with a conflict of interest or focusing on other technologies not related to digital dentistry or do not provide enough information regarding the selected topic. The search was guided by the specific objectives, and it was performed using the words ´aesthetic dentistry´, ´smile aesthetics´, ´digital smile analysis´, ´digital dentistry´, ´smile`, ´digital smile design`, `DSD´ and ´dental photography`. For Bias Assessment, the NOS and Cochrane Collaboration tool was applied. **Results**: A total of 13 studies regarding the use of DSD in dentistry were chosen based on the inclusion criteria. A total of 689 subjects were analyzed. The results demonstrated that nowadays DSD is used interdisciplinary in dentistry and that it improves communication, treatment predictability and patient satisfaction. **Discussion**: The DSD protocol improves treatment predictability, patient satisfaction and simplifies communication between dentists, patients, and dental technicians. DSD and Dental Photography are already of widespread and interdisciplinary use in contemporary dentistry.

Keywords*: Digital Smile Design; Digital Smile Analysis; Digital Dentistry; Dental Photography; Esthetic Dentistry*

Introduction

During the last years, the demands in dentistry are shifting from a mostly functional idea to a more holistic approach where aesthetics play a leading role for both patients and dentists. Even when pain or discomfort is the motive for a consultation with the dentist, patients ask nowadays for a treatment that is aesthetical and cost-effective. The main goal in dental smile design is to imitate teeth and design natural and pleasing smiles by respecting the individual and specific needs of the patient and improve proficiency of the cosmetic dental treatment (1). The invention of integrated techniques that provide tailored treatments for patients will be the future of digital dentistry (2). Furthermore, developments in digital esthetic dentistry enhance the workflow by allowing the development of models that enable a thorough characterization of tooth color, improving the effectiveness of esthetic dental restorations (3)(4). The assessment of ideal proportions of dental width and height, along with the positioning of the long axis of teeth (angles and inclinations) and the relationship between the colors, being white (teeth), pink (gingiva), and black (buccal corridors and black triangles), are all covered by DSD (5). Nowadays, among the

most common DSD programs described in the present literature, we can find Photoshop CS6 (Adobe Systems Incorporated), Keynote (Apple Inc.), Smile Designer Pro (SDP, Tasty Tech Ltd.)), Aesthetic Digital Smile Design (ADSD – Dr. Valerio Brini), Cerec SW 4.2 (Sirona Dental Systems Inc.), the DSD App by Coachmann (DSDAPP LLC), Planmeca Romexis Smile Design (PRSD) (Planmeca Romexis), Smilecloud Biometrics (Florin Cofar) and Smile Creator (Exocad)(6)(7). Digital Photography, imaging and design allows the patient to previsualize the anticipated outcome before the treatment is initiated, increasing the treatment's predictability and patients' satisfaction. DSD is also a very powerful marketing tool (8).

Material and Methods

This systematic review was conducted according to the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (9). The latest publications were investigated to provide an overview of the current use of digital smile analysis in aesthetic dentistry. The PICO question was used for the identification and structuring of the fundamental components of the systematic review, for which the following structured question was elaborated. Is Digital Smile Design improving patient satisfaction and treatment outcomes, and is it preferable to employ DSD? The research question was implemented into this systematic review by applying the PICO research model (Population, Intervention, Comparison, Outcome*)* with the following terms:

P: Patients who seek aesthetic dental treatment to improve their satisfaction with their smile
I: Intervention of guided digital smile design (DSD) approaches
C: No comparison parameter was defined
O: Patients satisfaction is higher and treatment outcome is efficient when employing DSD

-Information sources and data search:

All selected articles have been published in the English, Spanish or German language within the last 10 years, and the last search was performed on April 24, 2022. An automated search was carried out in the four databases mentioned above (PubMed, Medline Complete, Cochrane and Scopus) with the following keywords: ´aesthetic dentistry´, ´smile aesthetics´, ´digital smile analysis´, ´digital dentistry´, ´smile`, ´digital smile design`, `DSD´ and ´dental photography´. The last search was held on the 24.04.20222. The PubMed search was held by the following approach: ((aesthetic dentistry) [All Fields] AND (((digital dentistry) [MeSH Terms] OR digital smile design OR DSD) [All Fields] OR dental photography)) [MeSH Terms] AND ((((smile aesthetics) [MeSH Terms] OR ´smile' AND digital dentistry) [All Fields] OR digital smile analysis) "[MeSHTerms] .Search terms for Medline Complete, Cochrane and Scopus were ALL ((`digital smile design` OR `DSD`OR `digital dentistry` OR `digital smile analysis` OR `smile aesthetics` OR `smile` OR `aesthetic dentistry` AND `dental photography`))

-Inclusion criteria:

Articles published between2012 and 2022, Patients who underwent smile design with any type of DSD software, Randomized and non-randomized clinical trials Observational studies studying the effect of DSD and Articles in English, Spanish, and German language

-Exclusion criteria:

Articles involving patients with specific diseases, immunologic disorders or other oral risk-related systemic conditions or craniofacial discrepancies, Articles with a conflict of interest and Articles focusing on other technologies not related to digital dentistry or do not provide enough information regarding the selected topic.

-Systematic Search Strategy:

A three-stage selection process was carried out by two reviewers (VB and EG). The selection of studies was carried out by two reviewers. The first stage reviewed the titles to eliminate irrelevant studies. In the second stage, the summaries were reviewed and filtered according to type of study, type of digital intervention, number of patients, and outcome variables. The third stage consisted of a complete reading of each text and the data were extracted according to a predetermined data extraction form to confirm the eligibility of the studies.
- Data Extraction:

The data collected from the different articles is detailed by the name of the authors, year of publication, study design, number of included patients, patient satisfaction, DSD tool, further digital dental approaches like the use of intraoral scanners and CAD/CAM, follow up period and overall risk of bias. The information of the sample includes sample size, male/female ratio and mean and age range in years.

-Study Risk of Bias and Quality Assessment:

The quality of the included studies was assessed independently by two reviewers (VB and EG) to evaluate the methodological quality and risk of bias of all included articles. After removing duplicate sources, study titles and abstracts were reviewed to ensure they are relevant. Following that, studies that fulfilled the inclusion criteria were included after a full-text review. The included randomized controlled trials (RCTs) were considered "low risk of bias" when they met all the criteria, "high risk of bias" when one or more criteria were not met and therefore the study is considered to have a possible bias that weakens the reliability of the results and “uncertain bias” according to Cochrane Collaboration tool (either due to lack of information or uncertainty about the potential for bias). For each aspect of the quality assessment of the RCTS, the risk of bias was scored following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (http://handbook.cochrane.org). Each study featured varying degrees of heterogeneity in terms of design, case selection, and treatment applied. The methodological quality of observational studies was assessed with the Newcastle-Ottawa Scale (NOS).

Results

- Results of Literature searches/ Study Selection:

The article review and data extraction were performed according to the Preferred Reporting Items for Systemic Reviews and Metanalyses PRISMA flow diagram (Figure 1). The Literature research in the four online databases mentioned above (PubMed, Medline, Cochrane, and Scopus) identified a total of 237 potentially relevant articles. Out of the total number of 237 papers based on their title were selected, 62 were selected from PubMed, 79 from Medline, 12 from Cochrane and finally 84 from Scopus, being the first step of the research strategy. After 15 duplicates were removed, 222 articles were considered for title, abstract and summary evaluation and filtered according to intervention and outcome, the second step of the systematic research strategy. At the end of this evaluation, 72 relevant articles were identified for the third step of the research strategy, being the full text review. The full-text articles were subsequently obtained and thoroughly evaluated. For fulfilling the exclusion criteria 32 studies were excluded. For not meeting the inclusion criteria, 27 articles were excluded. A total of 13 relevant articles that fulfilled the inclusion criteria were selected for this systematic review (fig.1) after agreement by the two reviewers (VB, E

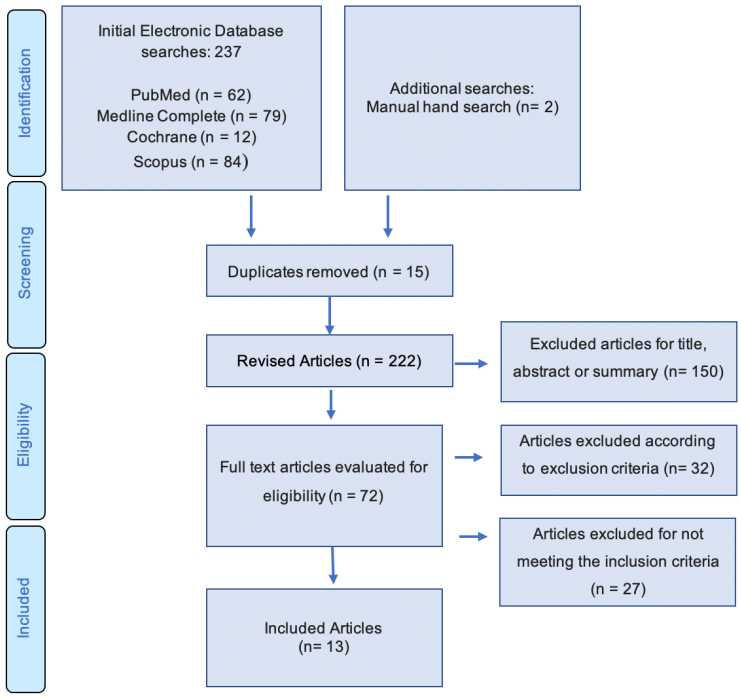

Fig. 1 Flow-Chart and study selection process for the systematic review

-Selected studies according to the inclusion criteria:

The study selection process is summarized in figure 1. The research's remaining 13 papers are constituted of 11 Observational studies and two RCTs and were confined to specific purposes based on the secondary objectives. Some investigations were beneficial for multiple developments. Two authors (VB, EG) assessed the risk of bias during the data extraction process. A total of 689 subjects were analyzed in the included studies. It can be highlighted that mostly young patients were included. 12 different DSD software were evaluated and accessed. Each study assessed different parameters and covered a total of five different dentistry fields (Restorative and Esthetic Dentistry, Prosthodontics, Orthodontics, Implantology and Oral surgery). Four of the included studies were interdisciplinary regarding their field of dentistry. In addition, three of the studies had a follow-up period between 2 and 4 years. Seven of the included studies had their focus on 2D and 3D DSD methods and accessed their main characteristics whereas parameters such as patients' satisfaction, efficiency, intuitiveness, understanding, reliability and measurement efficiency and stimulation degree. Five of the included studies on the other hand highlighted use and effectiveness of Digital Photography (DP) in Dentistry which is the basic requirement to develop DSD.

-Bias Assessment:

Risk of bias in the RCTs was categorized in accordance with the following criteria: low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met; unclear risk of bias (plausible bias that raises some doubt about the results) if one or more criteria were partially met; and high risk of bias (plausible bias that seriously weakens confidence in the results) if one or more of the criteria were not met. The included RCTS were considered an unclear risk of bias. For non-randomized observational studies, the risk of bias was considered low in 8 studies and medium in 1 study. The Newcastle–Ottawa Scale (NOS) (fig.3) was used to assess the risk of bias in the included

observational studies. One study scored a very low risk of bias with 9 out of 9 sections, while 6 studies had a low risk of bias with 8 out of 9 and only three studies scored only 7 out of the 9 having a medium risk of bias. There were various degrees of heterogeneity in each study design, case selection, and DSD approach among the studies.

	Sequence Generation	Allocation concealment	Binding of participants and personal	Blinding outcome assessment	Incomplete outcome date	Selective Reporting	Other Bias
Cattoni et al. (2021)	+	+	+	?	+	+	−
Ye et al. (2020)	+	+	?	−	+	?	−

Fig. 2 Randomized studies risk of bias following Cochrane´s guidelines

	Case Definition	Representativeness	Selection of controls	Definition of controls	Comparability of main outcome	Comparability for additional factors	Ascertainment of exposure	Same method for ascertainment for case and controls	Drop-out rate	Total
Cattoni et al. (2016)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Lavorgna et al. (2019)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Lv et al. (2022)	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Pires et al. (2022)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Lo Giudice et al. (2020)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Ortensi et al. (2021)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Ramaswamy et al. (2021)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Varghese et al. (2021)	☆	☆	☆	-	☆	-	☆	☆	☆	7
Iliev et al. (2020)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Husain et al. (2017)	☆	☆	☆	☆	☆	-	☆	☆	☆	8
Signori et al. (2018)	☆	☆	☆	☆	☆	-	☆	☆	☆	8

Fig. 3 Observational non-randomized studies according to Newcastle-Ottawa scale

-Results of Individual Studies:

The research of Cattoni et al. focuses on using digital photos from the 2D DSS software and matching a scanned file into the 3D DSS to generate a previsualization of teeth and a smile design. However, the current study has limitations, such as the small number of patients enrolled, demanding additional research with a wider sample of subjects to corroborate the findings. The new techniques shorten the time required to match data in order to create digital CAD/CAM-milling mockups and enhances the precision and reproducibility of the final mockup, and minimizes the trauma caused by handling hard dental tissues (10). In a subsequent study published in 2021, Cattoni et al. used a digital protocol that allows for a completely virtual planning of the exact position of the fixtures, allowing for high-precision surgical procedures and the use of virtually designed dental prostheses created with CAD/CAM methodologies for immediate implant loading (11).

Lavorgna et al. evaluates the accuracy of digital planning in dentistry by relating it to classic imaging 2D recording methods and examining the properties of four intraoral 3D scanners. Because there were no considerable disparities in measures, the conclusion is that 2D measures are faster and easier to use than all 3D approaches, therefore this research can assist to better define the field of application and the limitations of 2D approaches. The findings further suggested that In terms of the 2D/3D comparison, it's worth noting that 2D and 3D measurements can only be identical if 2D images are taken with the plane of the camera sensor absolutely perpendicular to the observed item and the surface of the observed subject is perfectly flat (12). Lv. et all findings where according to the patients' ratings, that the 3D digital simulated treatment plan showed obvious advantages in terms of intuitiveness and understanding of the treatment plan, as well as greater satisfaction rates than DSD with conventional wax-up. In the opinion of dental specialists, the 3D digital simulated treatment plan was also superior in terms of intuitiveness and treatment plan knowledge (13). According to Pires et al., the mock-up presented in the study effectively transferred the intended dental crown lengthening with DSD to the surgical procedure, and the esthetic

crown lengthening and restorative protocol proposed, based on the DSD concept and mock-up technique, was a predictable treatment to correct smile disharmony in all participating patients (14) (Table 1).According to Lo Giudice et al. with ANOVA analysis, important differences were detected across the 3D project and the prototyped-scanned anterior mock-ups (p 0.001), as well as between 3D project milled and milled-scanned anterior mock-ups (p 0.001). In comparison to milled mock-ups, prototyped mock-ups demonstrated smaller dimensional alterations from the original 3D idea, as well as greater clinical adaptability (15). Except for the mesial–distal widths of the lateral incisors and canine, which showed a substantial increase in digital scans, Ortensi et al. discovered no significant changes between the heights determined from the photos and those assessed from the digital scans. It's possible that the primary inclination of the dental parts involved is to blame for the disparity. The result reveals that the disparities in mesial–distal widths reported in photographs and digital scans were related to the transition from a 2D to a 3D environment (16). The findings of Ramaswamy et al. revealed that several smiling parameters measured can be used to rehabilitate the smile of dentate, partially dentate, and/or edentulous patients. The purpose of this study was to use pictures to examine various characteristics of the dento-labial-gingival complex. Dentists may diagnose, develop, create, and deliver esthetically pleasing new smiles using their knowledge of smile design combined with new and revolutionary dental technologies (5). Varghese et al. adopts a digital photographic design to accomplish a study on proportions on maxillary anterior teeth for esthetic smile. The golden percentage theory appears to be relevant to link the consecutive widths of the maxillary anterior teeth. The golden rectangle concept is useful for selecting aesthetically attractive proportions for maxillary central incisors (17)(Table 2). Iliev et al. uses *Rebel Simplicity technologies* to analyze 91 full-face smile images using dental Anatomical Combinations and computer analysis. The finding is that the technique resulted positive to ensure that the teeth and the facial type are in harmony. While smiling, digital facial maps allow an accurate and quick detection of the facial type. This examination allows to produce a digital design for an accurate and beautiful anterior tooth prosthetic replacement (18). Husain et al. establishes a two-dimensional dynamic video technology that records the smile employing multidirectional, remote-controlled, synchronously moving camera holding arms that hold digital single lens reflex cameras with high-definition video capture for use in everyday practice. The cameras in this setup can be used for both static and dynamic records in a consistent manner in terms of magnification and head position orientation. This is both efficient and economical (19). The outcomes of this study by Signori et al. revealed that the intraoral photography approach in the identification of restoration failures had good accuracy and reasonable agreement. Considering these findings, as well as the sensitivity, specificity, predictive values, and positive and negative probability ratios, we may infer that digital intraoral imaging can be used to assess the quality of restorations, particularly in the posterior teeth (20). Three-dimensional digital simulated design and implementation technique, according to Ye et al., can aid in achieving 3D digital simulated design before treatment and duplication to final restorations, as well as improve patient satisfaction in esthetic rehabilitation (21) (Table 3).

-Tables:

The following tables include the conclusion and other relevant data of the selected studies based on the specific objectives of this systematic review. The DSD system employed, and the main outcome of the included studies is summarized in Tables 1-3

Authors & Year of Publication	Study Design	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Cattoni et al. (2016) (10)	Observational Study 2- Years Follow-Up	2D-Digital Smile System (Digital Smile System Srl, Italy) 3D-Digital Smile System (EGS Srl, Italy)	28 patients (9 males, 19 females)	19-53 years of age	Patient satisfaction with DSD previsualization and the milling mock-up test	Visual analogical scale (VAS scale) to determine satisfaction with the digital smile design planning and the test in the form of the mockup	DSD is minimally invasive and facilitates diagnosis, improves communication with the patient, reduces processing times, and increases predictability of the results with very little discomfort and very high esthetic results. The patients considered DSD previsualization and the milling mockup test as very effective
Cattoni et al. (2021) (11)	RCT 4-Years Follow-Up	Smile Lynx software (8853 S.P.A., Milan, Italy) CAD software (CAD Lynx 8853 S.P.A., Milan, Italy)	50 patients randomly recruited and divided in 2 groups of 25	46 -85 years of age	Satisfaction with Digital smile previsualization, Mock-up test, Guided surgery, Immediate loading	Verbal Rating Scale (VRS)	Patients belonging to the digital group found digital smile preview and the mock-up test as very effective. All patients treated with a digital method reported lower values of during-surgery and post-surgery pain compared to patients rehabilitated using traditional treatment
Lavorgna et al. (2019) (12)	Observational study	Emerald, TRIOS, Photogrammetry and DSS	12 patients (6 female, 6 male)	25 to 35 years of age	Differences in measurements of the different tool data (Emerald, TRIOS, Photogrammetry and DSS) in terms of reliability and accuracy	Statistical analysis was performed using statistical software (Prism 8.0; GraphPad Software, Inc., La Jolla, CA, USA)	No significant differences emerged in the measurements made with the different scanners. The difficulty on comparing 2D with 3D investigations was highlighted
Lv et al. (2022) (13)	Observational study	2D DSD Software not further specified, intervention according to the established protocol of DSD3D Workflow by 3D-SHAPE, (Denmark)	11 patients (2 males and 9 females)	19 to 36 years of age	Difference between Intuitiveness, understanding, and satisfaction or help (dentists) in 3D treatment stimulation or 2D DSD plus wax-up technique	Visual analogue scales & Statistical analysis. Paired t-test was performed, and the level of significance was set at $P < 0.05$	3D digital plans are more intuitive (8 .9 ± 0.8 vs 5.9 ± 1.0) to understand the plans from the other specialists (8.9 ± 0.7 vs 6.1 ± 1.0) and helpful to their treatment plans (8.7 ± 0.9 vs 5.9 ± 1.4)
Pires et al. (2022) (14)	Observational Study 2-year follow-up	PowerPoint (Microsoft) for DSD planning of all cases	6 patients (5 females, 1 male)	22 to 35 years of age	Mean and standard deviation of the dental crown length in the anterior teeth at baseline, immediately postoperatively at the 2-year follow-up, and the years of age crown length planned by the DSD	Statistical Analysis: The measurements were repeated twice with an interval of 1 week, and the Pearson's correlation coefficient was used to assess the calibration of the evaluator concerning the analyzes performed	Esthetic crown lengthening procedure based on the DSD concept and mock-up technique proposed in this study was a predictable protocol for smile disharmony treatment in all the patients

Table 1 – Summary of present DSD methods and dental treatment planning software

Authors & Year of Publication	Study Design	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Lo Giudice et al. (2020) (15)	Observational Study	2D DSS system (version 1.11.1-alpha.1, Digital Smile System Srl, Italy); DSS CAD software (DSS3D. Beta.12977, EGS Srl, Italy)	10 patients (8 females and 2 males, mean age)	N/A	Matching percentage of prototyped and milled mock-ups with 3D project Comparison of linear measurements (mm3) performed on 3D project, prototyped, and prototyped-scanned anterior mock-ups	Statistical analysis: The trueness of both prototyped and milled mock-ups was assessed by using the Paired Student's t test. The two-way analysis of variance (ANOVA) was used to assess if there were statistical differences among the linear measurements obtained at each stage of the entire CADCAM workflow	Both prototype and milled mock-ups showed a slight dimensional increment in comparison with the original 3D project. Prototyped mock-ups demonstrated few dimensional changes from the original 3D project compared to the milled mock-ups as well as a greater clinical adaptation
Ortensi et al. (2021) (16)	Observational study	2D DSS (Digital Smile System Srl); 3D Exocad® DentalCAD 2.2 Valletta software (Exocad GmbH) Shape 3D Viewer software (3Shape A/S)	30 patients (18 women and 12 men)	20 - 50 years of age	Linear measurements of the maxillary right central and lateral incisors and canine; mesial–distal widths of the restorations Consistency between the 2D virtual preview of the treatment and the restorations	The Friedman test, Bonferroni, and Dunn post hoc tests were used, comparing the linear measurements of the 2D and 3D plans and the final veneers (α =.05). Measurement data were statistically analyzed using a software program (Prism 8.0; GraphPad Software, San Diego, CA, USA)	The customized are clinically adequate, like the 2D and 3D plans previsualization. However, there are significant differences between the picture and digital scans as well as between the 2D and 3D plans.
Ramaswamy et al. (2021) (5)	Observational Study	DP DSLR [Single-lens reflex digital camera (NIKON)	120 patients (60 males and 60 females)	male mean age: 21.97 female mean age: 22.20.	240 photographs, 2 of each patient being a close-up (natural and forced smiles) and facial photographs Parameters assessed were Smile Arc; Gingival Visibility; Facial and dental midline; Gingival zenith pattern and relationship between the smile arc and lower lip	Statistical analysis Chi-square test and Fisher's exact test were used to compare the link between gender and various parameters. Comparison between two groups or various parameters was done by non-parametric Mann–Whitney "U" test. The p value of 0.05 was statistically significant.	DP offers the dental professional an array of the possibility of visual reconstruction of the various stages of treatment. With DP as an aid, the dentists can design and correct the smile for the utmost satisfaction of the patients.
Varghese et al. (2021) (17)	Observational Study	Adobe Photoshop CS5; (Adobe Systems, Inc, San Jose, Calif.)	150 subjects (male/female ratio N/A)	18 – 25 years of age	Full-face digital images of subjects in smile will be made, with the subject in a seated position. Golden ratio, Golden rectangle & RED (Recurring esthetic dental) proportion were assessed	The data were statistically analyzed using paired Student's t-test (level of significance $P \leq 0.05$)	The golden ratio appears to be relevant to link the consecutive widths of the maxillary anterior teeth. The golden rectangle concept is useful for selecting aesthetically attractive dimensions for maxillary central incisors. The RED proportion is an inadequate approach for relating the sequential widths of the maxillary anterior teeth, according to DP and analyses.

Table 2 – Summary of present DSD methods and dental treatment planning software

Authors & Year of Publication	Study Design	Software and Equipment	Sample		Parameter Assessed	Assessment Tool	Main Outcome
Iliev et al. (2020) (18)	Observational Study	Digital Facial Maps with Rebel Simplicity systems	42 male and 49 female subjects	N/A	Subjects were categorized into four main types: Strong, dynamic, delicate, and calm by 27 landmark points and 12 basic lines	IBM SPSS Modeler software	Dental Anatomical Combinations in combination with Rebel Simplicity systems is a constructive way to ensure harmonious unity between the teeth and the facial type. Digital facial maps provide reliable and fast identification of the facial type while smiling
Husain et al. (2017) (19)	Observational Study	The captured video frames were saved as pictures using screen-shot software and analyzed using custom software called "smile mesh."	96 subjects (48 female and 48 male)	18 -28 years of age	Reliability and measurement errors for images made on the same day (3 images) and on 3 different days	Reliability expressed by Pearson correlation coefficient. Results of the paired t test for the mean difference (P values).	Capturing standardized high-definition video and still images simultaneously from 3 positions is described. It resulted practical, effective, and easy to learn and implement in the orthodontic practice
Signori et al. (2018) (20)	Observational Study	The digital intraoral camera CS 1200 (Carestream Health Inc, Rochester, New York, USA	55 patients with 198 restorations, aged between (128 posterior and 70 anterior restorations)	18 - 57 years of age	Intraoral photographs of anterior and posterior restorations were classified based on FDI criteria according to the need for intervention: no intervention, repair, and replacement. The prevalence of failures was explored.	Evaluations were performed by an expert in restorative dentistry (gold standard evaluator) and 3 trained dentists (consensus) Validity was accessed by sensitivity, specificity, likelihood ratio and predictive values.	The assessment of DP performed by intraoral camera is an indirect diagnostic method valid for the evaluation of dental restorations, mainly in posterior teeth. This method is effective due the higher detection of defects provided by the images, which are not always clinically relevant.
Ye et al. (2020) (21)	RCT	3D digital simulated design was used to predict the post-treatment effect in the experimental group and 2D digital smile design in the control group	30 patients were recruited and randomly assigned into 2 groups (10 males, 20 females)	Experimental group mean age: 36.0±10.5 Control group mean age: 32.0±6.7	The simulation degree of DSD and the similarity between preoperative design and postoperative rehabilitation were assessed	Visual analogue scales (VAS) and satisfaction rate	Three-dimensional digital simulated design and implementation technique aid in achieving 3D digital simulated design before treatment and duplication of the final restorations and can enhance the patients' satisfaction with the treatment outcome than in the control group (P<0.05).

Table 3 – Summary of present DSD methods and dental treatment planning software

Discussion

One of the most significant facial functions, the smile, is frequently used to assess success or failure in life, particularly from a patient's perspective. One´s smile is a sensible but also intimate facial feature and everything that comes with the expectations to modify it is a highly emotional concern for a patient, that the dentist needs to keep in mind while designing a new smile (7). Nowadays, digital technology is frequently employed for facial identification from images or videos by facial contour analysis (18). As part of the esthetic rehabilitation process, a full examination is required, which includes a face analysis, dental-facial analysis, and dental analysis. The importance of a good communication with the patient in all dental aesthetic treatments cannot be emphasized enough. Any effort should be made in modern dentistry to improve the communication of diagnosis and therapy with the patients and amongst dentists. In this regard, virtual planning combined with a mock-up-based approach improves the accuracy of aesthetic treatments by enhancing the knowledge of patients' demands and the information-sharing process between prosthodontists and lab technicians (15).

-Digital Smile Design and dental treatment planning software:

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 (7). Omar et al. conducted a literature review in which different software were evaluated (*Photoshop CS6, Keynote, Planmeca Romexis Smile Design, CEREC SW 4.2, Aesthetic Digital Smile Design, Smile Designer Pro, DSD App*, and *VisagiSMile*). The possibility of having functions concerning oral structures, such as teeth or gums, makes the work much quicker and more predictable in this study, different programs were evaluated. The highest scores were observed in *Photoshop CS6* and *Keynote*; therefore, more comprehensive esthetic analysis can be achieved using these programs even though they are not specific for dental practice. Most programs specific for dental practice seem to overlook facial esthetic parameters and focus on dentogingival and dental esthetic parameters instead.

The *DSD App* on the other hand is being developed by Christian Coachman who published studies on the use of Keynote for digital smile design and, therefore, shows similarities with the image editing software (7). Classic aesthetic evaluation and treatment guidelines were based before on 2D measurements. More recent clinical studies evaluated 3D surface analysis of scanned teeth and faces and showed findings in contrast to traditional paradigms and classic studies on aesthetic parameters. Prosthetic treatment planning is accomplished by using a digital workflow in a study by Cattoni et al. According to the authors, the limit of these technologies is a two-dimensional (2D) workflow. The approach used by the authors in this case gives a completely digital CAD/CAM procedure to reduce mistakes. The dental lab receives the three-dimensional (3D) planning and fabricates the prosthetic pieces. The combination of the DSD digital process with the stl-files from the digital optical impression enables for the laboratory production of these objects. The authors also add to their findings that Digital technology, such as a computer with one of the various DSD software programs, a digital camera, or even just a smartphone, is already widespread in today's dentistry clinics (10). As mentioned per Cervino et al., with software advances soon, it will be possible to design a patient's rehabilitation by integrating files from a CT scan or a Cone Beam, as well as the.stl files from an oral impression or a facial scan and a photo. All of this ensures that the patients receive the therapy they seek, as well as their personal satisfaction (3).

Lo Giudice et al. on the other hand claimed that employing software that has both 2D and 3D capabilities, such as *Exocad*, will speed up the workflow and make the entire process more fluid and efficient (15).

According to Cattoni et al. DSD plays also in important role in modern Implantology. The therapeutic efficacy of rehabilitations based on the use of fewer implants, with a high aesthetic and functional output, is now generally accepted in Implantology. With the advancement of technology, it is envisaged that a digital workflow would become even more simple and accessible to any dental professional (11). As in another systematic review mentioned by Cicciú et al. evaluation on how digital workflows provide accuracy and predictability was done. The authors ruled it a reliable alternative for full arch rehabilitations with a marginal fit precision and also underlined the trend how digital techniques will substitute the analogical ones more and more, improving the quality of oral rehabilitations, the clinical economics and also the perception by the patients (22).

Face and smile aren't perfectly symmetrical; rather, they're dynamic. According to Garcia et al., the employment of current digital technologies in the dental clinic provides new potential. The authors looked at a front maxillary prosthesis rehabilitation that was created using Digital Smile Design. They find that it is effective for diagnosing and also serves as a useful tool for recommending treatment regimens to patients (23). The DSD approach allows for esthetic planning by establishing reference lines and employing extra- and intraoral digital photographs to achieve the final dental design. This method expands the diagnostic range and aids dentists and technicians in recognizing treatment boundaries and difficulties including tooth asymmetries, disharmonies, and esthetic violations. DSD is a new instrument around cosmetic and restorative dentistry that has only lately been introduced. For objective esthetic evaluations and virtual therapeutic planning, DSD apps are used to alter photos and/or scanned models of patients. However, A range of 2D and 3D dental and non-dental CAD software tools and superimposition methods can be used to create a facially oriented diagnostic wax-up, which might be overwhelming for dental practitioners (24).

-Digital Photography in Dentistry:

Dental photography provides the dentist with a variety of options for visual reconstruction of various phases of therapy. Clinicians can develop and

fix smiles for patients' ultimate satisfaction using DP as a tool. Clinical diagnosis is a subjective procedure that can lead to a variety of interpretations, even among experienced physicians, depending on how cautious they are. Taking these findings into account, as well as sensitivity, specificity, predictive values, and positive and negative likelihood ratios, the authors conclude that intraoral DP can be used to examine the quality of restorations, particularly in the posterior teeth. The study by Signori et al. manifests that the use of intraoral digital imaging to evaluate dental restorations is a reliable procedure (20). Ramaswamy et al. concluded that DP provides the dentist with a wide range of visual reconstruction options at different phases of therapy of the dental treatment. Clinicians can use DP to develop and restore smiles for the highest level of patient satisfaction. Clinical photography has become an important aspect of routine dentistry practice, according to the authors (5). Husain et al. introduced a new approach to capture standardized high-definition video and still images simultaneously from 3 positions. He describes the technique as efficient and simple. The authors express the great interest in 3D capturing of the human face. However, standardized dynamic 3D video capture and a measuring system are still in the experimental phases and also that the huge amount of data produced by 3D video imaging needs high-end computer equipment for processing (19).

-Benefits and advances by using DSD:

As mentioned by Cicciú et al. the introduction of new technology in the fields of medicine and dentistry is resulting in advancements that enable dentists to develop techniques and treatments that can enhance the quality of life of their patients (22). Pires concluded that from a communicative point of view virtual planning combined with a mock-up-based approach improves the predictability of aesthetic restorations by enhancing the comprehension of patients' expectations and the information-sharing process between prosthodontists and the dental lab workers (14). Currently, the trend is observed that the awareness and aesthetic expectations on dental treatments are increasing. Cervino et al. further point out the advantage that patients can visualize their future rehabilitations before the treatment starts, which can serve an essential medico-legal purpose (3). As Omar et al. have also remarked, not all DSD applications on the market today have the same level of skill when it comes to full analysis of dentofacial aesthetic characteristics. Although simplicity of use is one of the most important factors to consider when selecting a DSD program, other factors such as cost, time efficiency, systematic digital workflow and organization, and compatibility of the program with CAD/CAM or other digital systems may also impact the clinician's decision (7). In another systematic review, Joda et al described the whole computerized approach as the potential to be a game changer in fixed prosthodontics. In a modernized treatment concept, major benefits could include lower manufacturing costs, improved time efficiency, and patient satisfaction (25). By offering a speed of treatment planning and a reliability of results, Cervino et al. emphasize that advancement in the digital dentistry sector is constant and will be of increasing importance to dentistry (3).

- Patient satisfaction and understanding regarding DSD approaches:

According to Lv et al. 3D digital treatment simulation helps both patients and dental specialists to improve treatment understanding and facilitates dental specialists for decision-making before complex esthetic rehabilitation. Highlighting the ratings from the patients, the authors concluded that 3D digital simulated treatment plan showed obvious advantages in the aspects of intuitiveness and understanding of the treatment plan, and the satisfaction rates were also higher than DSD plus conventional wax-up (13). As concluded by Joda et al. the appropriate indication is a

prerequisite and the correct application is crucial for the success of the overall therapy, and finally, for a satisfied patient (25). A systematic review conducted by Ye et al. assessed the degree of digital design simulation and the similarity between preoperative design and postoperative rehabilitation using a VAS scale in both groups, as well as the patient satisfaction rat with the treatment. The authors concluded that achieving a 3D digital simulated design before treatment and duplication to the final restorations can improve the patients' satisfaction in esthetic rehabilitation (21). Industrial advancement appears to be outpacing scientific evidence. This is a significant result, and one that will stimulate the attention of clinicians who must determine whether or not to engage with DSD and adopt comprehensive digital processes in their dental practices (25). Overall, the scientific level of clinical evidence was lacking in the field of DSD and DSS. Only two RCTs could be included for this systematic review. The study designs and follow-up periods as well as the defined outcomes were heterogeneous. This also applied to the lower included evidence level being the observational studies which draws the conclusion that more qualitative research on DSD in the future is needed.

Conclusion

With the evidence of the included studies to provide an overview about how present digital smile design methods are used in contemporary dentistry, this systematic review concludes that:

1. The DSD methodology enables for aesthetic planning by using extra- and intraoral digital pictures to establish reference lines and the final dental design. This approach broadens the diagnostic spectrum and assists dental professionals in identifying treatment restrictions and risk factors such as asymmetries, disharmonies, and aesthetic violations. Since DSD is a relatively new digital innovation in dentistry further research is still lacking to investigate it to a deeper extent. However, there is already and increased usage trend of DSD approaches.
2. The DSD protocol improves treatment predictability and simplifies communication between dentists, patients, and dental technicians. DSD and Dental Photography are already of widespread and interdisciplinary use in contemporary dentistry. It is the creation of a strong communication protocol that allows for an efficient dental treatment, while also increasing its perceived value.
3. By integrating the patient into a founder of his own new smile, DSD not only improves treatment planning and the smile designing process, but also the patient's satisfaction with the treatment outcome. Results have demonstrated that the previsualization with DSD is considered as very effective by patients and dental professionals.

Conflict of Interest
The authors declare that they have no conflict of interest in this study

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