The Trend in the Application of Digital Smile Design Technology: Insights from 2016 to 2023

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Abstract

Background: Technology has brought about a lot of changes in dentistry, especially in dental materials and procedures. Tools for digital planning, as Digital Smile Design (DSD), should be applied.

Aim: The objective of this study is to analyze the application of DSD in various dental specialties.

Materials and Methods: This study was conducted on 24 studies from clinical as well as animal studies that were selected according to an inclusion criterion that emphasized the use of DSD in restorative dentistry, periodontology, dental implant and various other fields in addition to an exclusion criterion in which patient-based studies with a specific disease or insufficient data were excluded. Analysis was conducted via a one-sample T-test.

Results: DSD was mostly applied in prosthetic and restorative dentistry (47.6%), followed by periodontal treatment. The latest common applications were in guided bone regeneration and maxillofacial surgery (4.8%), the statistical analysis showed significant differences between all these percentages

Conclusions: The major use of DSD is in prosthetic and restorative treatment and then in periodontology.

2) DSD can enhance communication with patients, treatment planning and results prediction

Keywords: Digital Smile Design; restorative dentistry; dental software; dental design.

1. Introduction

Aesthetics and cosmetic dentistry have seen great developments in recent years and other aspects of dentistry, such as dental implantology and periodontal treatment. Many reasons are responsible for these, such as improvements in laboratory procedures and anatomical criteria, which increase the beauty of the patient's smile. Implementing the computer-aided design/computer-aided manufacturing (CAD/CAM) technology has been one of the most important evolutions in this field since it permits obtaining professional clinical results that are both aesthetically successful and preserve function.

The reasonable cost of CAD/CAM technique has resulted in its global use, in addition to its small size and ease of use, even for small outpatient clinics. This customized software will further improve its use for the dentist by digitizing the complete rehabilitation procedure and communication with patients. A quick internet search will give the possible suitable software programmers, amongst which the DSD method type is one of the most powerful ones. With various studies showing improved patient-dentist communication and treatment planning based on supported decision aids [1], the DSD serves to enhance the patient and dentist experience, also providing a stronger base and personalized recommendations to be considered.

A major advantage of digital rehabilitation throughout the DSD is the opportunity for patients to see how they will look following the treatment. This technique allows for better planning and more predictable aesthetic and functional results [2, 3]. The union of three-dimensional technology and the evolving field of bioengineering has continued to push the limits, with virtual simulation software now allowing the dentist to make a three-dimensional simulation prior to placement in a patient's mouth. Using finite element simulations, the DSD can be assessed for a wide range of dental applications that include implants and prosthetics and many other applications, which guarantees the safety and effectiveness of the treatment [4, 5].

Digital Smile Design offers a comprehensive treatment protocol that begins from a well-calibrated picture and from standardized reference lines used in facial analysis that allow for obtaining harmonious results in the side view as in the frontal one [4, 5 and 6]. There are several lines of reference when dealing with the horizontal view, as, for example, the interpupillary line and intercommissural line that are important to obtain a balanced and esthetic face. Aesthetic smile is a result of a combination of different elements, including the teeth, gingiva, mucosa, lips and skin, all are influenced by symmetry and shape. The approach can also be considered as a complicated process, but it facilitates good communication with the patient by enabling them to see the digital outcome results. Digital Smile Design and similar software solutions are useful to clinicians, who can use these technologies to customize treatment. In addition, the application of high-quality images provides the opportunity for individual treatment planning that is adapted to the anatomy of each patient, ensuring both functional and aesthetic harmony [4].

This article aims to discuss the predominant clinical application of Digital Smile Design in various fields of dentistry, and discuss its reliability and effectiveness as well as its limitations. Finally, this work underlines the shift that these digital tools may bring to the future of dental rehabilitation.

2. Methods

The following research questions have been formulated to guide the study process:
1-What are the applications for Digital Smile Design in each field of dentistry?
2- What is the patient and clinical experience when using the Digital Smile Design?

- **Sources of information:** Relevant articles were identified through a search of electronic and other manual references, utilizing PubMed and the Dentistry and Oral Sciences Source.
- **Search Strategy:** The primary keyword utilized in the database search was "Digital Smile Design." This term was selected to capture a broad spectrum of data related to the subject while ensuring that the search was not overly restrictive (Figure 1).
- **Selection of Studies** Two independent reviewers analyzed the studies based on pre-established inclusion and exclusion criteria. A dual review process was carried out during the evaluation of full-text articles to ensure thorough and unbiased selection.
- **Types of Selected Manuscripts** published in English. Excluded materials encompassed letters, editorials, and doctoral theses, as they were not directly relevant to the review's objectives. The review incorporated a variety of study designs, including prospective and retrospective follow-up studies, clinical trials, cohort studies, case-control studies, case series, animal studies, and literature reviews. All these studies explored the role of Digital Smile Design in rehabilitation and restorative dentistry.

Full texts of potentially relevant studies were obtained and assessed based on the following criteria:

- **Inclusion criteria:** Studies focused on the use of Digital Smile Design in restorative dentistry and its associated benefits.
- **Exclusion criteria**: Studies involving patients with specific diseases, immunological disorders, or other systemic conditions that negatively impact oral health. Studies were also excluded if they lacked sufficient information on the topic or if their titles and abstracts were not available in English.
- **Sequential Search Strategy**: The selection process began with an initial review of article titles to filter out irrelevant studies, case reports, and non-English literature. Abstracts of the remaining studies were then reviewed, and full-text evaluations were conducted in the final stage to confirm eligibility based on the inclusion and exclusion criteria.
- **Selected studies:** A total of twenty-four studies published between 2016-2023 were selected, focusing on advancement in digital smile design and were reviewed.
- **Data Extraction**: Data from the selected studies were independently extracted and categorized based on variables aligned with the aim of this study. This step ensured a systematic approach to data organization. Data Collection is as follows:
  - The extracted data were compiled into specific categories for analysis, including the Author and year of publication, and the specific dental field where Digital Smile Design was applied.
  - Then, the total number of application cases reported, the number of application cases of DSD in each field and the percentage of DSD applications in each field were obtained
- **Risk of Bias Assessment**: To ensure the credibility of the review, a risk of bias assessment was conducted by two authors during the data extraction process. This evaluation utilized the Cochrane Collaboration's tool for assessing bias in research studies. Studies were classified into four categories: low risk (all criteria met), moderate risk (one criterion missing), high risk (two or more criteria missing), and unclear risk (insufficient details for evaluation) [4, 7].
- **Statistical analysis of data**
  - Descriptive statistics include tables for results, bar charts and pie charts
  - Descriptive statistics include a one-sample T- Teste for to investigate the level of significance between the percentage of DSD applications for the different fields

Individual characteristics of the selected studies were evaluated, with a primary focus on the fields of Digital Smile Design applications, as displayed in Fig. 1.
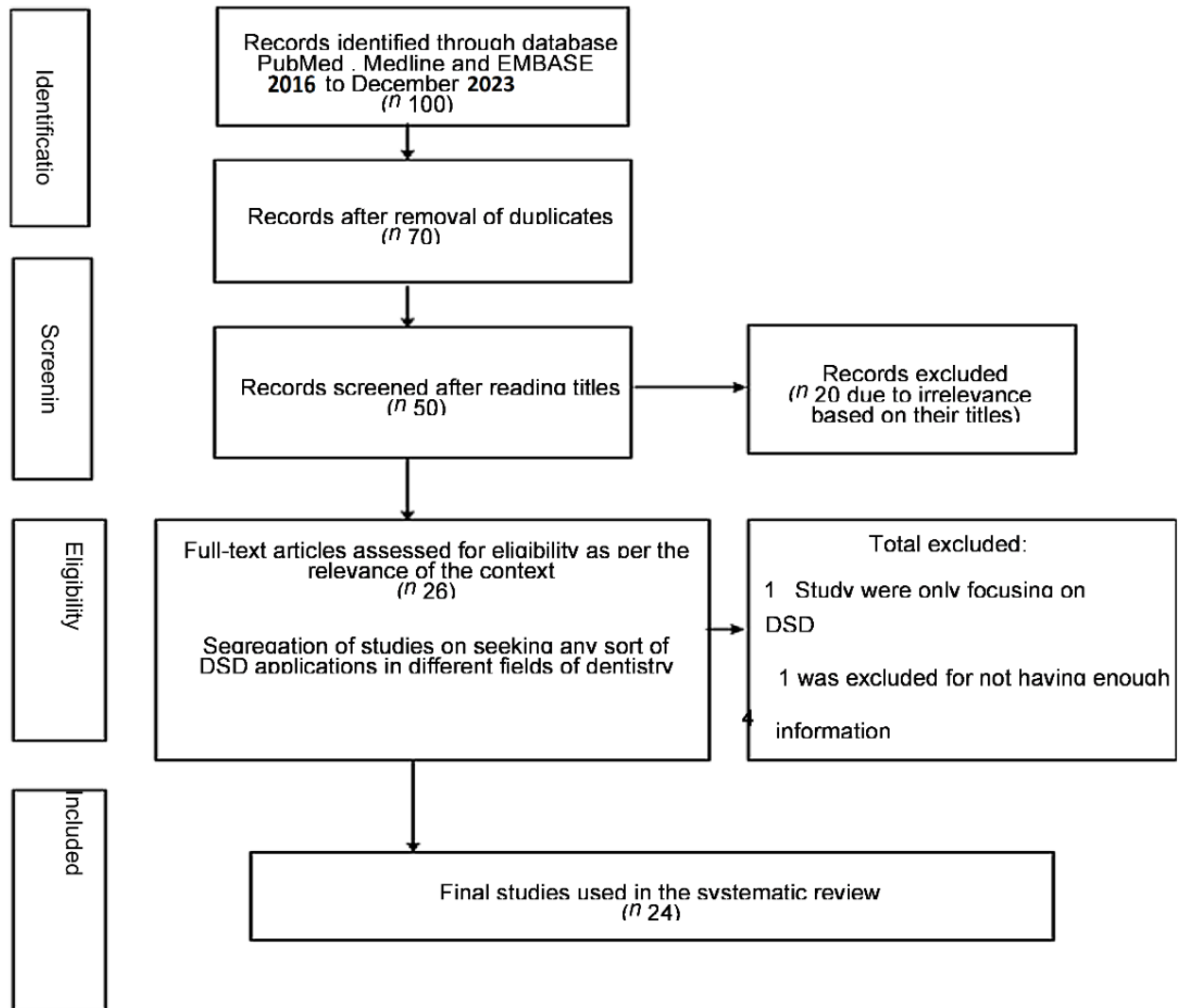
Fig. 1 The PRISMA Flow Diagram

The assessed fields with their symbols were as follow:

1- Restorative dentistry (R&S)

2- Periodontal surgery (P.S.)

3- Implantology----------------------(Imp.)

4- Guided bone regeneration (G.R.)

5- Orthodontics (Orth.)

6- Maxillofacial surgery (M.S.)

7- Others (O.)

3. Limitation

This study encountered several limitations. One notable limitation is that only studies published in English were included, which may introduce publication bias. Additionally, there was a considerable degree of heterogeneity observed in study designs, case selections, and treatment methodologies among the included studies. This study primarily does not engage in a statistical comparison of data

across the individual studies reviewed. Despite being a contemporary subject, a limited number of comprehensive studies are available. Nevertheless, our study delineates the various fields in dentistry where this digital tool is applied, and we anticipate that further research will solidify its scientific foundation. The availability of more scientific articles that provide detailed insights into the reliability, accuracy, and predictability of DSD methods would significantly enrich the discourse and serve as a valuable resource for future reviews.

4. Results

The results of the data collection were compiled from all articles considered for this study, focusing on Digital Smile Design (DSD) and its application in different fields of dentistry, and the total number of application cases reported and is shown in Table 1.

Table 1. Result of the evaluation of the previous 24 studies

References	Field of DSD Applications						
	R. & S.	P. S.	Imp.	G. R.	Orth.	M. S.	O.
Clark et al. [8]	-	*	-	-	*	-	-
Cattoni et al. [9]	*	-	-	-	-	-	*
Coachman et al. [10]	*	-	-	-	*	-	
Coachman et al. [11]	*	-	-	-	-	-	-
Da Rosa et al. [12]	*	-	-	-	-	-	-
Delilbeyoglu et al. [13]	-	-	-	-	-	-	*
Daher et al. [14]	-	-	-	-	-	-	*
Frizzera et al. [15]	*	-	-	-	-	-	-
Garcia et al, [16]	*	-	-	-	-	-	-
Halley [17]	*	*	-	-	-	-	*
Lombardo et al. [18]	*	*	*	-	-	-	-
McLaren et al. [19]	*	-	-	-	-	-	-
Meereis et al. [20]	*	-	-	-	-	*	-
Omar et al. [21]	-	-	-	-	-	-	*
Paredes-G et al. [22]	*	-	-	-	*	*	-
Smith et al (23)	*	-	-	-	-	-	-
Pimentel et al. [24]	*	-	-	-	-	-	-
Pinzan-V et al. [25]		*	-	-	-	-	-
Rojas-V et al. [26]	*	*	*	-	-	-	-
Santos et al. [27]	*	*	-	-	-	-	-
Stanley et al. [28]	*	*	-	-	-	-	-
Tak On et al. [29]	*	-	-	-	-	-	-
Trushkowsky et al. [30]	*	-	-	-	-	-	-
Veneziani [31]	*	*	*	*	-	-	-
Toral * = 24							

Then the total number of application OJMS cases reported and the number of application cases of DSD in each field and the percentage of DSD applications in each field were obtained as shown in Table 2, Figs. 2 and 3.

Table 2: Number of cases and percentage of DSD application

Field of DSD Applications	No. of Cases	Percentage (%)
R&P	20	47.6
P. S.	7	16.7
IMP.	3	7.1
G. R.	2	4.8
Orth.	4	9.5
M. S.	2	4.8
O.	4	9.5
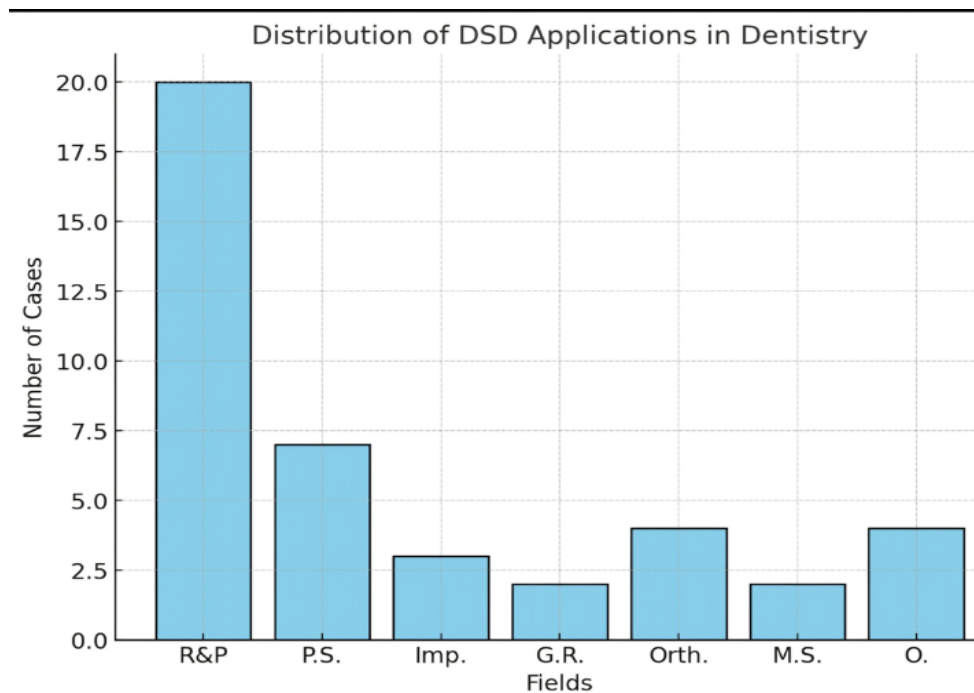
Fig. 2 Numbers of cases (of DSD applications) in different field of dentistry

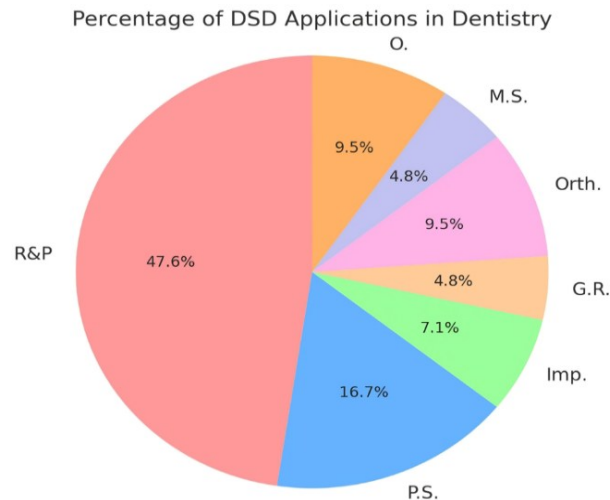Percentage of DSD Applications in Dentistry

Fig. 3 The percentage of cases (of DSD applications) in different field of dentistry

However, the Statistical analysis of data is presented as follows:

- Descriptive statistics include

It is obvious from Table 2, Figs. 2 and 3 that the prosthetic and dental restoration got the most prevalent use of DSD (20 cases, 47.6%), followed by its applications in periodontal treatment. The least application was in the field of guided bone regeneration as well as maxillofacial surgery (2 cases, 4.8%). Descriptive statistics include a one-sample T-test to investigate the level of significance between the percentage of DSD applications for the different fields. The result is as follows:

T-statistic =-5.78

P-value <0.05, including a significant difference between 47.6% (R&P) and the other percentage

Result of risk of bias assessment: An assessment of the risk of bias for each study indicated that most studies were classified as having low risk. A few studies were also identified as having a moderate risk of bias.

5. Discussion

The recent advancements in technology can change patient care in dentistry, enabling fewer errors in the treatment. Digital smile design (DSD) is a revolutionary method of treatment planning and patient assessment in dentistry. Its visual components can help the dentist to predict and simulate the final result accurately [27].

Digital Smile Design (DSD) is a great designing system in which a computer provides a digital smile simulation of what the future smile would look like. This solves a common problem in which patients receive treatment without having been fully realistic image in their mind about the outcomes. DSD enables the patient to be part of the decision-making when planning their aesthetic and functional rehabilitation. For the clinician, it can be a useful tool for customizing treatment plans to meet patient expectations [1]. Clark et al. [8] investigate the use of DSD in periodontal surgery to fix gummy smiles. They found that it uses aid to obtain better satisfaction results and reduces the risk of postoperative complications.

The work of Cattoni et al [9] demonstrated the disadvantage of 2D techniques in prosthetic dentistry. They reported the benefits of three-dimensional (3D) planning by CAD/CAM systems because it is a more accurate device and of much limiting errors. Coachmen et al. [10] discuss the

application of DSD in orthodontics. Coachman et al [11]. in a second study, discuss the use of DSDs in full-mouth rehabilitations and obtaining accurate results even in difficult cases.

Da Rosa et al. [12] review the application of DSD in orthodontic treatment. Delilbeyoglu et al. [13] in their study reported the rehabilitation of high lip line patients with the aid of DSD. Daher et al. [14]. explored low-cost solutions for DSD analysis using high-resolution mobile phone photography. Their results indicate that without budget limitations, efficient digital planning can be carried out, expanding the range of DSD possibilities.

Frezera et al. [15] showed how the program can aid in the planning of the periprosthetic surgery in detail. Garcia et al. [16]. focus on the anterior maxilla, which is difficult to rehabilitate. They found that the use of DSD can ensure optimal functional and aesthetic results. In the work of Halley [17], the author considered the 3D planning to change aesthetic dentistry. DSD digital not only significantly improves the treatment results for patients and clinicians but also helps predict them. He also suggested that this new technique is gaining popularity over time.

Lombardo et al. [18] concentrated on the digital treatment planning and the virtualization of dental treatment results. The DSD, according to their study, made treatment in a shorter time with a higher level of accuracy. McLaren et al. [19] explained how that technology is changing the whole future of cosmetic dentistry. These technologies allow clinicians to enhance and modify smiles digitally, providing patients with the best possible results.

Meereis et al. [20] explored DSD's role in aesthetic rehabilitation, combining gingival plastic surgery with restorative dentistry. Their findings demonstrated that lithium disilicate glass ceramic veneers, designed with DSD tools, provided highly predictable results, ensuring functional and aesthetic satisfaction. Omar et al. [21] reviewed several software programs used in Digital Smile Design, their research demonstrated that while general-purpose software can be adapted for dental use, specialized tools significantly enhance planning efficiency and precision.

Paredes-Gallardo et al. [22] give a particularly challenging case that showcases the power of DSD, involving a second-class brachyphosis patient with mandibular asymmetry. The case required complex surgical interventions, including osteotomies and genoplasty, followed by orthodontic treatment and prosthetic rehabilitation. DSD was instrumental in planning these treatments, ensuring a well-coordinated and precise approach to correcting the patient's dental and facial asymmetry. Smith et al. [23] demonstrated that CEREC CAD/CAM can be combined with DSD and result in faster and more accurate patient prosthetic restoration. Whereas, Piment et al. [24] focus on the use of DSD in restorative and prosthetic dentistry.

Pinzan-Vercelino et al. [25] investigated the use of DSD in the aesthetic rehabilitation of patients with midline diastema between the upper front teeth and according to their study, the DSD proved to be effective for such a case. Rojas et al. [26] evaluated the application of DSD in full-mouth rehabilitation in implant-supported and grafted patients, and DSD helps solve severe bone deficiencies and achieve long-term successful restoration.

Santos et al. [27] explained what is the impact of DSD on periodontal surgery and concluded that DSD is very helpful in cases such as clinical crown lengthening. An article by Stanley [28] described the importance of applying DSD for temporomandibular joint (TMJ) patients, thus enabling and minimally invasive prosthetic rehabilitation and reducing discomfort during processing.

Tak On et al. [29] demonstrated the preventive properties of prosthetic treatment while using DSD, dentists can incorporate minimal intervention approaches that can reach the desired results. Trushkowsky et al. [30] confirmed the significance of DSD in aesthetic evaluations of oral rehabilitation and their role in increasing patient satisfaction. Veneziani et al. [31] studied the application of DSD to complicated dental cases usually in need of more than one specialist and concluded that DSD could be used for patient full rehabilitation treatment, combining orthodontists, prosthodontists and oral surgeons in one convenient visit.

These results highlight the increasing involvement of digital technologies in contemporary dental planning. As a very useful digital tool, DSD has been demonstrated to facilitate precision and predictability of treatments in numerous studies [18, 24]. Nonetheless, though DSD has proven effective, a lot of studies necessitate continuing to conduct further studies to ensure long-term success [15, 24, and 26].

The cooperation of several specialists associated with dentistry, such as oral surgeons, prosthodontists, orthodontists, and even radiologists, is very necessary to obtain the best results when performing DSD, thus resulting in a better and faster outcome [17, 22]. Other challenges in the use of DSD in complex and rare dental cases also need to be studied more in future research. As the technology continues to develop each day but researchers expect such digital systems to be used for both complex and simple cases [18, 24].

Moreover, the integration of DSD into routine practice is expected to continue to enhance the patient experience. By offering detailed visual simulations and predictable treatment plans, patients are empowered to make informed decisions about their dental care. This approach fosters greater trust and satisfaction, as patients feel more involved in the treatment process [15, 17]. As the dental field embraces digital technologies, it is essential to focus not only on technological advancements but also on training and education for practitioners. Ensuring that dental professionals are proficient in using DSD software and integrating it into their workflows will be critical to the successful adoption of these tools across the industry [22, 24].

In this study the result showed that the percentages of DSD applications is shifting towards the restorative and prosthetic dentistry these findings could be attributed to the fact that esthetic out com is the major concern for the patient seeking restorative and prosthetic treatment but from the analysis of the previous studies we predict in the future of dentistry, will likely see a shift towards even more personalized treatment plans, with DSD playing a central role in most of the fields of dentistry.

6. Conclusions

From analyzing the previous 24 selected studies and calculating the percentage of DSD applications in different fields of dentistry, the following conclusions were drawn:

1- In conclusion, the literature surrounding Digital Smile Design indicates that this tool offers substantial benefits for both clinicians and patients. Patients can visualize their proposed rehabilitation prior to commencement. Recent advancements in digital techniques have markedly improved the utility and effectiveness of DSD.
2- DSD, as reported, can enhance the quality and predictability of rehabilitative outcomes.
3- The integration of digital instruments with other digital files, including radiographs and dental laboratory machinery, enables more predictable rehabilitative procedures.

4- The most prevalent DSD application is in the field of prosthetic and restorative dentistry, while the least is in surgery and guided bone regeneration

5- The continuous evolution of technology in this sector promises to yield an increase in DSD application in all fields in the future

6- Further studies are needed in this topic due to its importance and ongoing improvements in technology

Conflict of Interest

There is no conflict of Interest

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